

DESCRIPTION

POLYMER AND POLYMERIC LUMINESCENT ELEMENT
COMPRISING THE SAME

TECHNICAL FIELD

The present invention relates to a polymer and a method for producing the same, an ink composition that contains the polymer, and a polymeric light-emitting device (hereinafter sometimes referred to as polymeric LED) using the polymer.

BACKGROUND ART

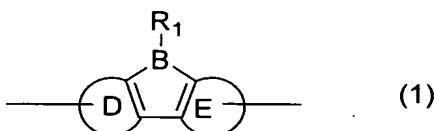
Various types of high-molecular-weight light-emitting materials or charge transport materials are being examined, because, unlike low-molecular-weight light-emitting materials or charge transport materials, they are soluble in solvents and can form a light-emitting layer or charge transport layer in a light-emitting device, depending on the coating method employed. Of such materials, polyphenylenevinylene derivatives, polyfluorene derivatives and polyphenylene derivatives are well-known.

DISCLOSURE OF THE INVENTION

The object of this invention is to provide a novel polymer usable as a light-emitting material, charge transport material, or the like, a method for

producing the same, and a polymeric light-emitting device using the polymer.

After directing tremendous effort toward the above described subject, the present inventors have 5 found that a polymer that includes a repeating unit represented by the following formula (1):



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and having a number-average molecular weight, in terms of polystyrene, of 10^3 to 10^8 can be applied to a light-emitting material, charge transport material or the like and have finally accomplished this invention.

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BEST MODE FOR CARRYING OUT THE INVENTION

In the above formula (1), rings D and E each represent an aromatic ring.

Examples of such aromatic rings include:

20 aromatic hydrocarbon rings such as benzene, naphthalene, anthracene, phenanthrene, pyrene, perylene, tetracene and pentacene rings; and heteroaromatic rings such as pyridine, pyrimidine, pyridazine, pyrazine, quinoline, isoquinoline, 25 quinoxaline, quinazoline, acridine, phenanthroline, thiophene, benzothiophene, dibenzothiophene, thiophenoxide, benzothiophenoxide, dibenzothiophenoxide, thiophenedioxide,

benzothiophenedioxide, dibenzothiophenedioxide, furan, benzofuran, dibenzofuran, pyrrole, indole, dibenzopyrrole, silole, benzosilole, dibenzosilole, borole, benzoborole and dibenzoborole rings. Of these 5 aromatic rings, aromatic hydrocarbon rings are preferable, and benzene, naphthalene and anthracene rings are particularly preferable.

The rings D and E optionally have a substituent selected from the group consisting of 10 alkyl, alkoxy, alkylthio, aryl, aryloxy, arylthio, arylalkyl, arylalkoxy, arylalkylthio, arylalkenyl, arylalkynyl, amino, substituted amino, silyl, substituted silyl, silyloxy and substituted silyloxy groups, halogen atoms, acyl, acyloxy, imino, amide, 15 imide, monovalent heterocyclic, carboxyl, substituted carboxyl and cyano groups.

The above described alkyl groups may be straight-chain, branched-chain or cyclic alkyl groups. The number of carbons that each of the alkyl groups has 20 is usually about 1 to 20 and preferably 3 to 20.

Specific examples of the alkyl groups include methyl, ethyl, propyl, i-propyl, butyl, i-butyl, t-butyl, pentyl, hexyl, cyclohexyl, heptyl, octyl, 2-ethylhexyl, nonyl, decyl, 3,7-dimethyloctyl, lauryl, 25 trifluoromethyl, pentafluoroethyl, perfluorobutyl, perfluorohexyl and perfluorooctyl groups. Preferable are pentyl, hexyl, octyl, 2-ethylhexyl, decyl and 3,7-dimethyloctyl.

The above described alkoxy groups may be straight-chain, branched-chain or cyclic alkoxy groups. The number of carbons that each of the alkoxy groups has is usually about 1 to 20 and preferably 3 to 20.

5 Specific examples of the alkoxy groups include methoxy, ethoxy, propyloxy, i-propyloxy, butoxy, i-butoxy, t-butoxy, pentyloxy, hexyloxy, cyclohexyloxy, heptyloxy, octyloxy, 2-ethylhexyloxy, nonyloxy, decyloxy, 3,7-dimethyloctyloxy, lauryloxy, trifluoromethoxy,

10 pentafluoroethoxy, perfluorobutoxy, perfluorohexyl, perfluorooctyl, methoxymethyloxy and 2-methoxyethyloxy. Of these groups, preferable are pentyloxy, hexyloxy, octyloxy, 2-ethylhexyloxy, decyloxy and 3,7-dimethyloctyloxy groups.

15 The above described alkylthio groups may be straight-chain, branched-chain or cyclic alkylthio groups. The number of carbons that each of the alkylthio groups has is usually about 1 to 20 and preferably 3 to 20. Specific examples of the alkylthio

20 groups include methylthio, ethylthio, propylthio, i-propylthio, butylthio, i-butylthio, t-butylthio, pentylthio, hexylthio, cyclohexylthio, heptylthio, octylthio, 2-ethylhexylthio, nonylthio, decylthio, 3,7-dimethyloctylthio, laurylthio and trifluoromethylthio

25 groups. Of these groups, preferable are pentylthio, hexylthio, octylthio, 2-ethylhexylthio, decylthio and 3,7-dimethyloctylthio groups.

The number of carbons that each of the above

aryl groups has is usually about 6 to 60 and preferably 7 to 48. Examples of the aryl groups include phenyl, C₁-C₁₂ alkoxyphenyl ("C₁-C₁₂" indicates the number of carbons the aryl group has is 1 to 12 and the same is 5 true hereafter), C₁-C₁₂ alkylphenyl, 1-naphthyl, 2-naphthyl, 1-anthracenyl, 2-anthracenyl, 9-anthracenyl and pentafluorophenyl groups. Of these aryl groups, C₁-C₁₂ alkoxyphenyl and C₁-C₁₂ alkylphenyl groups are preferable. The term "aryl group" means an atomic 10 group derived from an aromatic hydrocarbon by removal one of hydrogens on the aromatic nucleus. The aromatic hydrocarbons includes those having a condensed ring and those formed by combining two or more independent benzene rings or condensed rings directly or via a 15 group such as vinylene.

Specific examples of C₁-C₁₂ alkoxy groups include methoxy, ethoxy, propyloxy, i-propyloxy, butoxy, i-butoxy, t-butoxy, pentyloxy, hexyloxy, cyclohexyloxy, heptyloxy, octyloxy, 2-ethylhexyloxy, 20 nonyloxy, decyloxy, 3,7-dimethyloctyloxy and lauryloxy groups.

Specific examples of C₁-C₁₂ alkyl groups include methyl, ethyl, propyl, i-propyl, butyl, i-butyl, t-butyl, pentyl, hexyl, cyclohexyl, heptyl, 25 octyl, 2-ethylhexyl, nonyl, decyl, 3,7-dimethyloctyl and lauryl groups.

The number of carbons that each of the above described aryloxy groups has is usually about 6 to 60

and preferably 7 to 48. Examples of the aryloxy groups include phenoxy, C₁-C₁₂ alkoxyphenoxy, C₁-C₁₂ alkylphenoxy, 1-naphthyloxy, 2-naphthyloxy and pentafluorophenoxy groups. Of these groups, C₁-C₁₂ 5 alkoxyphenoxy and C₁-C₁₂ alkylphenoxy groups are preferable.

The number of carbons that each of the above described arylthio groups has is usually about 6 to 60 and preferably 7 to 48. Examples of the arylthio 10 groups include phenylthio, C₁-C₁₂ alkoxyphenylthio, C₁-C₁₂ alkylphenylthio, 1-naphthylthio, 2-naphthylthio and pentafluorophenylthio groups. Of these arylthio groups, C₁-C₁₂ alkoxyphenylthio and C₁-C₁₂ alkylphenylthio groups are preferable.

15 The number of carbons that each of the above described arylalkyl groups has is usually about 7 to 60 and preferably 7 to 48. Examples of the arylalkyl groups include: phenyl-(C₁-C₁₂)-alkyl groups such as phenylmethyl, phenylethyl, phenylbutyl, phenylpentyl, 20 phenylhexyl, phenylheptyl and phenyloctyl; phenyl-(C₁-C₁₂)-alkyl groups; C₁-C₁₂ alkoxyphenyl-(C₁-C₁₂)-alkyl groups; C₁-C₁₂ alkylphenyl-(C₁-C₁₂)-alkyl groups; 1-naphtyl-(C₁-C₁₂)-alkyl groups; and 2-naphtyl-(C₁-C₁₂)-alkyl groups. Of these arylalkyl groups, C₁-C₁₂ 25 alkoxyphenyl-(C₁-C₁₂)-alkyl groups and C₁-C₁₂ alkylphenyl-(C₁-C₁₂)-alkyl groups are preferable.

The number of carbons that each of the above described arylalkoxy groups has is usually about 7 to

60 and preferably 7 to 48. Examples of the arylalkoxy groups include: phenyl-(C₁-C₁₂)-alkoxy groups such as phenylmethoxy, phenylethoxy, phenylbutoxy, phenylpentyloxy, phenylhexyloxy, phenylheptyloxy and

5 phenyloctyloxy; C₁-C₁₂ alkoxyphenyl-(C₁-C₁₂)-alkoxy groups; C₁-C₁₂ alkylphenyl-(C₁-C₁₂)-alkoxy groups; 1-naphtyl-(C₁-C₁₂)-alkoxy groups; and 2-naphtyl-(C₁-C₁₂)-alkoxy groups. Of these arylalkoxy groups, C₁-C₁₂ alkoxyphenyl-(C₁-C₁₂)-alkoxy groups and C₁-C₁₂

10 alkylphenyl-(C₁-C₁₂)-alkoxy groups are preferable.

The number of carbons that each of the above described arylalkylthio groups has is usually about 7 to 60 and preferably 7 to 48. Examples of the arylalkylthio groups include: phenyl-(C₁-C₁₂)-alkylthio groups; C₁-C₁₂ alkoxyphenyl-(C₁-C₁₂)-alkylthio groups; C₁-C₁₂ alkylphenyl-(C₁-C₁₂)-alkylthio groups; 1-naphtyl-(C₁-C₁₂)-alkylthio groups; and 2-naphtyl-(C₁-C₁₂)-alkylthio groups. Of these arylalkoxy groups, C₁-C₁₂ alkoxyphenyl-(C₁-C₁₂)-alkylthio groups and C₁-C₁₂

20 alkylphenyl-(C₁-C₁₂)-alkylthio groups are preferable.

The number of carbons that each of the above described arylalkenyl groups has is usually about 8 to 60 and preferably 8 to 48. Examples of the arylalkenyl groups include: phenyl-(C₂-C₁₂)-alkenyl groups; C₁-C₁₂ alkoxyphenyl-(C₂-C₁₂)-alkenyl groups; C₁-C₁₂ alkylphenyl-(C₂-C₁₂)-alkenyl groups; 1-naphtyl-(C₂-C₁₂)-alkenyl groups; and 2-naphtyl-(C₂-C₁₂)-alkenyl groups. Of these arylalkenyl groups, C₁-C₁₂ alkoxyphenyl-(C₂-C₁₂)-alkenyl

groups and C_1 - C_{12} alkylphenyl-(C_2 - C_{12})-alkenyl groups are preferable.

The number of carbons that each of the above described arylalkynyl groups has is usually about 8 to 5 60 and preferably 8 to 48. Examples of the arylalkynyl groups include: phenyl-(C_2 - C_{12})-alkynyl groups; C_1 - C_{12} alkoxyphenyl-(C_2 - C_{12})-alkynyl groups; C_1 - C_{12} alkylphenyl-(C_2 - C_{12})-alkynyl groups; 1-naphtyl-(C_2 - C_{12})-alkynyl groups; and 2-naphtyl-(C_2 - C_{12})-alkynyl groups. Of these 10 arylalkynyl groups, C_1 - C_{12} alkoxyphenyl-(C_2 - C_{12})-alkynyl groups and C_1 - C_{12} alkylphenyl-(C_2 - C_{12})-alkynyl groups are preferable.

The above described substituted amino groups mean amino groups substituted by one or two groups 15 selected from the group consisting of alkyl, aryl, arylalkyl and monovalent heterocyclic groups. The number of carbons that each of the substituted amino groups has is usually about 1 to 60 and preferably 2 to 48.

20 Examples of the substituted amino groups include methylamino, dimethylamino, ethylamino, diethylamino, propylamino, dipropylamino, i-propylamino, diisopropylamino, butylamino, i-butylamino, t-butylamino, pentylamino, hexylamino, 25 cyclohexylamino, heptylamino, octylamino, 2-ethylhexylamino, nonylamino, decylamino, 3,7-dimethyloctylamino, laurylamino, cyclopentylamino, dicyclopentylamino, cyclohexylamino, dicyclohexylamino,

pyrrolidyl, piperidyl, ditrifluoromethylamino,
 phenylamino, diphenylamino, C_1 - C_{12} alkoxyphenylamino,
 di((C_1-C_{12}) -alkoxyphenyl)amino, di((C_1-C_{12}) -
 alkylphenyl)amino, 1-naphthylamino, 2-naphthylamino,
 5 pentafluorophenylamino, pyridylamino, pyridazinylamino,
 pyrimidylamino, pyrazylamino, triazylamino, phenyl- (C_1-C_{12}) -alkylamino,
 C_1-C_{12} alkoxyphenyl- (C_1-C_{12}) -alkylamino,
 C_1-C_{12} alkylphenyl- (C_1-C_{12}) -alkylamino, di((C_1-C_{12}) -
 alkoxypyhenyl- (C_1-C_{12}) -alkyl)amino, di((C_1-C_{12}) -
 10 alkylphenyl- (C_1-C_{12}) -alkyl)amino, 1-naphthyl- (C_1-C_{12}) -
 alkylamino, 2-naphthyl- (C_1-C_{12}) -alkylamino and carbazoyl
 groups.

The above described substituted silyl groups
 mean silyl groups substituted by one, two or three
 15 groups selected from the group consisting of alkyl,
 aryl, arylalkyl and monovalent heterocyclic groups.
 The number of carbons that each of the substituted
 silyl groups has is usually about 1 to 60 and
 preferably 3 to 48.

20 Examples of the substituted silyl groups
 include trimethylsilyl, triethylsilyl, tripropylsilyl,
 tri-i-propylsilyl, dimethyl-i-propylsilyl, diethyl-i-
 propylsilyl, t-butylsilyldimethylsilyl,
 pentyldimethylsilyl, hexyldimethylsilyl,
 25 heptyldimethylsilyl, octyldimethylsilyl, 2-ethylhexyl-
 dimethylsilyl, nonyldimethylsilyl, decyldimethylsilyl,
 3,7-dimethyloctyl-dimethylsilyl, lauryldimethylsilyl,
 phenyl- (C_1-C_{12}) -alkylsilyl, C_1-C_{12} alkoxyphenyl- (C_1-C_{12}) -

alkylsilyl, C_1-C_{12} alkylphenyl- (C_1-C_{12}) -alkylsilyl, 1-naphthyl- (C_1-C_{12}) -alkylsilyl, 2-naphthyl- (C_1-C_{12}) -alkylsilyl, phenyl- (C_1-C_{12}) -alkyldimethylsilyl, triphenylsilyl, tri-*p*-xylylsilyl, tribenzylsilyl,
5 diphenylmethylsilyl, *t*-butyldiphenylsilyl, dimethylphenylsilyl, trimethoxysilyl, triethoxysilyl, tripropyloxysilyl, tri-*i*-propylsilyl, dimethyl-*i*-propylsilyl, methyldimethoxysilyl and ethyldimethoxysilyl groups.

10 The above described substituted silyloxy groups mean silyloxy groups substituted by one, two or three groups selected from the group consisting of alkyl, aryl, arylalkyl and monovalent heterocyclic groups. The number of carbons that each of the
15 substituted silyloxy groups has is usually about 1 to 60 and preferably 3 to 48.

Examples of the substituted silyloxy groups include trimethylsilyloxy, triethylsilyloxy, tripropylsilyloxy, tri-*i*-propylsilyloxy, dimethyl-*i*-
20 propylsilyloxy, diethyl-*i*-propylsilyloxy, *t*-butylsilyldimethylsilyloxy, pentyldimethylsilyloxy, hexyldimethylsilyloxy, heptyldimethylsilyloxy, octyldimethylsilyloxy, 2-ethylhexyl-dimethylsilyloxy, nonyldimethylsilyloxy, decyldimethylsilyloxy, 3,7-
25 dimethyloctyl-dimethylsilyloxy, lauryldimethylsilyloxy, C_1-C_{12} alkoxyphenyl- (C_1-C_{12}) -alkylsilyloxy, C_1-C_{12} alkylphenyl- (C_1-C_{12}) -alkylsilyloxy, 1-naphthyl- (C_1-C_{12}) -alkylsilyloxy, 2-

naphthyl-(C₁-C₁₂)-alkylsilyloxy, phenyl-(C₁-C₁₂)-alkyldimethylsilyloxy, triphenylsilyloxy, tri-p-xylylsilyloxy, tribenzylsilyloxy, diphenylmethysilyloxy, t-butyldiphenylsilyloxy,

5 dimethylphenylsilyloxy, trimethoxysilyloxy, triethoxysilyloxy, tripropyloxysilyloxy, tri-i-propylsilyloxy, dimethyl-i-propylsilyloxy, methyldimethoxysilyloxy and ethyldimethoxysilyloxy groups.

10 Examples of the above described halogen atoms include fluorine, chlorine, bromine and iodine.

The number of carbons that each of the above described acyl groups has is usually about 2 to 20 and preferably 2 to 18. Specific examples of the acyl

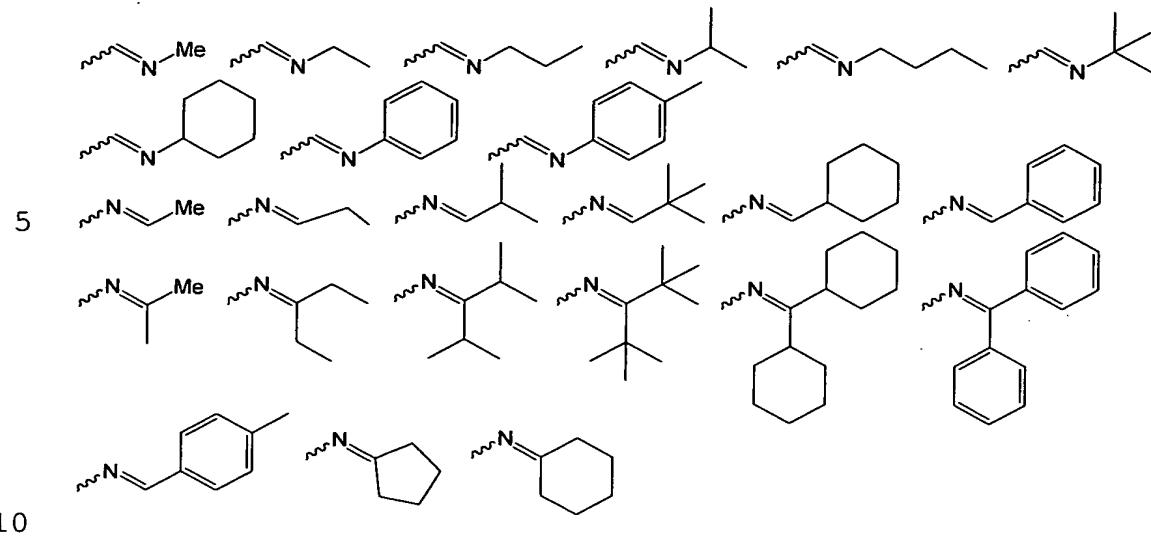
15 groups include acetyl, propionyl, butyryl, isobutyryl, pivaloyl, benzoyl, trifluoroacetyl and pentafluorobenzoyl groups.

The number of carbons that each of the above described acyloxy groups has is usually about 2 to 20

20 and preferably 2 to 18. Specific examples of the acyloxy groups include acetoxy, propionyloxy, butyryloxy, isobutyryloxy, pivaloyloxy, benzoyloxy, trifluoroacetyloxy and pentafluorobenzoyloxy groups.

The number of carbons that each of the above

25 described imino groups has is usually about 2 to 20 and preferably 2 to 18. Specific examples of the imino groups include compounds represented by the following structural formulae.

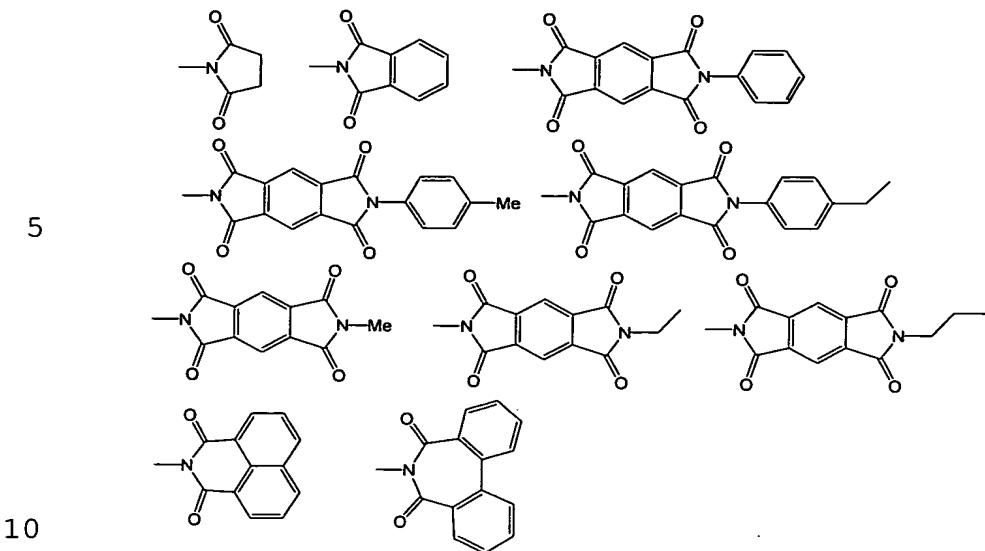


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The number of carbons that each of the above described amide groups has is usually about 1 to 20 and preferably 2 to 18. Specific examples of the amide groups include formamide, acetamide, propionamide, butyramide, benzamide, trifluoroacetamide, pentafluorobenzamide, diformamide, diacetamide, dipropionamide, dibutyramide, dibenzamide, ditrifluoroacetamide and dipentafluorobenzamide.

15

The number of carbons that each of the above described imide groups has is usually about 4 to 20 and preferably 6 to 18. Specific examples of the imide groups include groups represented by the following structural formulae.



In the above formulae, Me represents a methyl group.

The term "monovalent heterocyclic group" means an atomic group derived from a heterocyclic compound by removal one of hydrogens on the heterocyclic ring. The number of carbons that each of the monovalent heterocyclic groups has is usually 3 to 60 and preferably 4 to 20. This number does not include the number of carbons the substituents of the heterocyclic compound have. The term "heterocyclic compound" means an organic compound having a ring structure in which the ring structure is composed of not only carbon atoms, but also a heteroatom(s) such as oxygen, sulfur, nitrogen, phosphorus and boron.

Examples of monovalent heterocyclic groups include thienyl, C₁-C₁₂ alkylthienyl, pyrrolyl, furyl, pyridyl and C₁-C₁₂ alkylpyridyl. Of these groups, preferable are thienyl, C₁-C₁₂ alkylthienyl, pyrrolyl and C₁-C₁₂

alkylpyridyl groups.

The number of carbons that each of the above described substituted carboxyl groups has is usually about 2 to 60 and preferably 2 to 48. The term

5 "substituted carboxyl group" means a carboxyl group substituted by an alkyl, aryl, arylalkyl or monovalent heterocyclic group. Specific examples of the carboxyl groups include methoxycarbonyl, ethoxycarbonyl, propoxycarbonyl, i-propoxycarbonyl, butoxycarbonyl, i-
10 butoxycarbonyl, t-butoxycarbonyl, pentyloxycarbonyl, hexyloxycarbonyl, cyclohexyloxycarbonyl, heptyloxycarbonyl, octyloxycarbonyl, 2-ethylhexyloxycarbonyl, nonyloxycarbonyl, decyloxycarbonyl, 3,7-dimethyloctyloxycarbonyl,
15 dodecyloxycarbonyl, trifluoromethoxycarbonyl, pentafluoroethoxycarbonyl, perfluorobutoxycarbonyl, perfluorohexyloxycarbonyl, perfluoroctyloxycarbonyl, phenoxy carbonyl, naphthoxycarbonyl and pyridyloxycarbonyl groups.

20 Of the substituents as exemplified above, the substituents containing an alkyl chain(s) may be straight, branched or cyclic chains, or combinations thereof. Examples of the substituents which are not straight chains include isoamyl, 2-ethylhexyl, 3,7-
25 dimethyloctyl, cyclohexyl and 4-(C₁-C₁₂)-alkylcyclohexyl. The substituents containing alkyl chains may form a ring with the tips of the two alkyl chains linked together. Further, the methyl group or

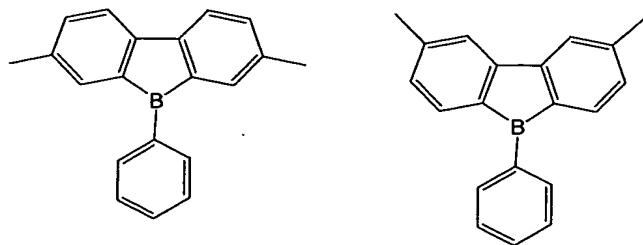
methylene group as a part of the alkyl chain may be substituted by a group containing a heteroatom, or a methyl group or methylene group substituted by one or more fluorine atoms. Examples of such heteroatoms 5 include oxygen, sulfur and nitrogen atoms.

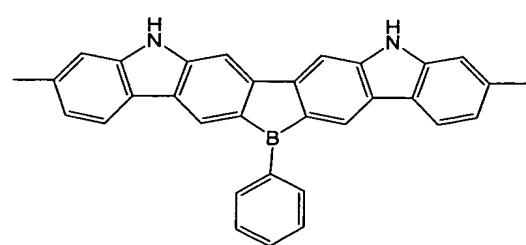
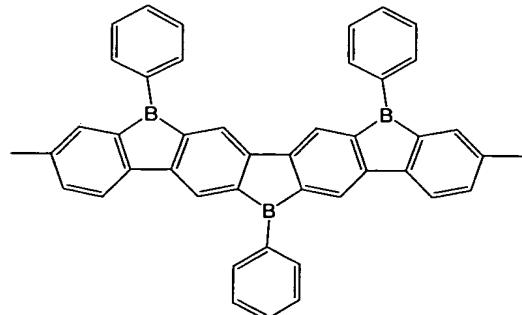
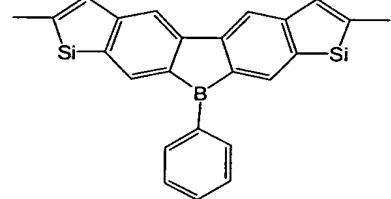
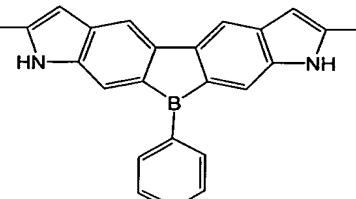
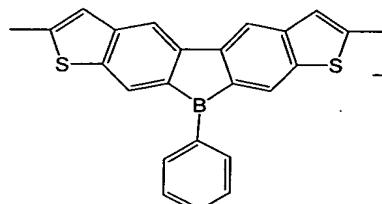
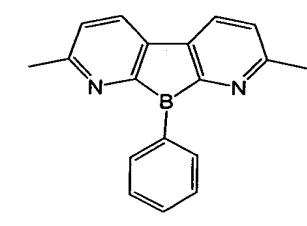
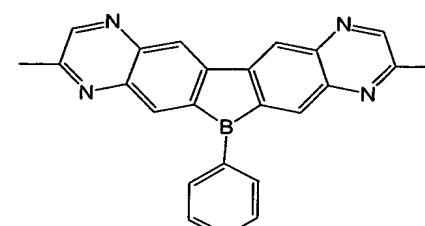
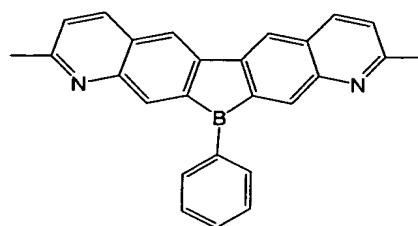
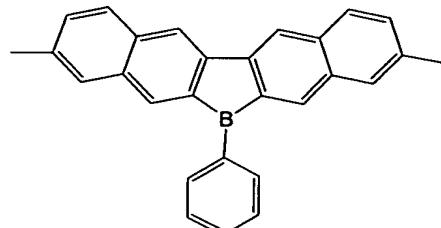
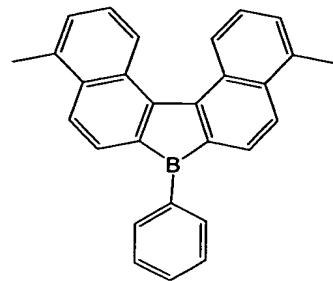
R₁ in the above described formula (1) represents a hydrogen atom, or an alkyl, alkoxy, alkylthio, aryl, aryloxy, arylthio, arylalkyl, arylalkoxy, arylalkylthio, arylalkenyl, arylalkynyl, 10 amino, substituted amino, silyl, substituted silyl, silyloxy, substituted silyloxy or monovalent heterocyclic group, or a halogen atom.

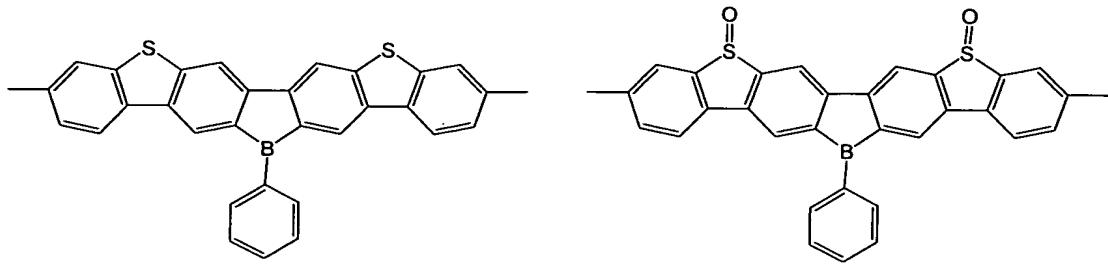
Specific examples of alkyl or alkoxy groups as R₁ include the same alkyl or alkoxy groups 15 illustrated as the substituents of the rings D and E.

Preferably, R₁ is an alkyl, aryl, substituted amino or monovalent heterocyclic group and more preferably an aryl, substituted amino or monovalent heterocyclic group.

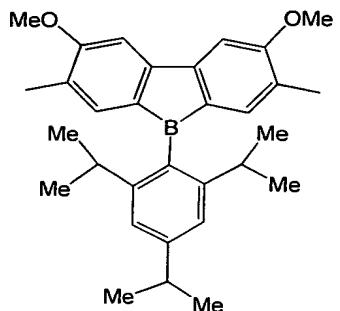
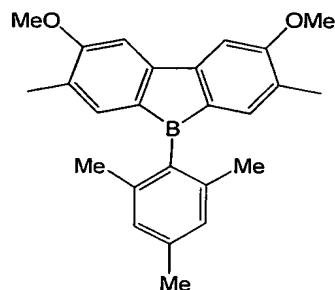
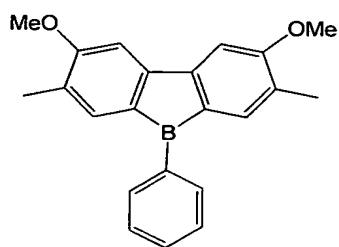
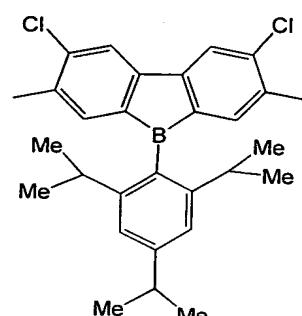
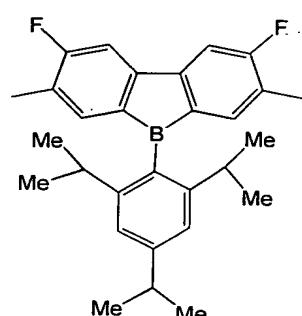
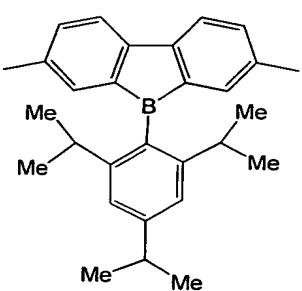
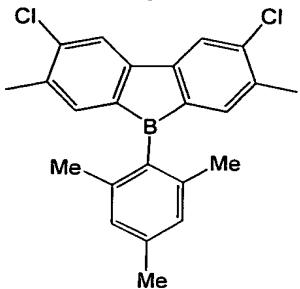
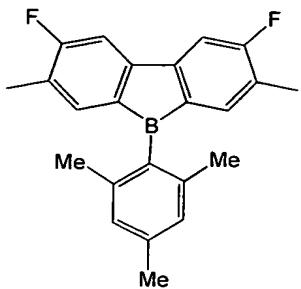
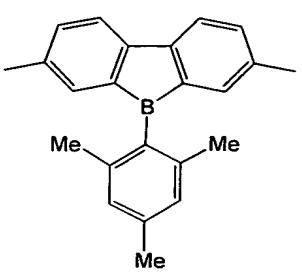
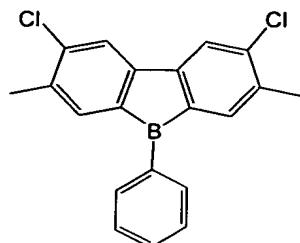
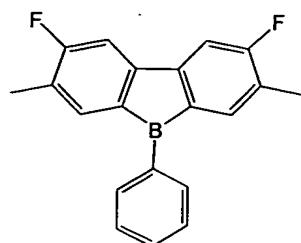
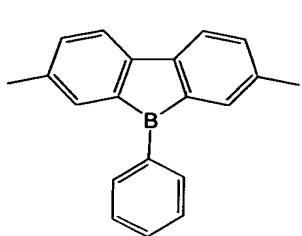
20 The basic structures of repeating units represented by the formula (1) are as follows.

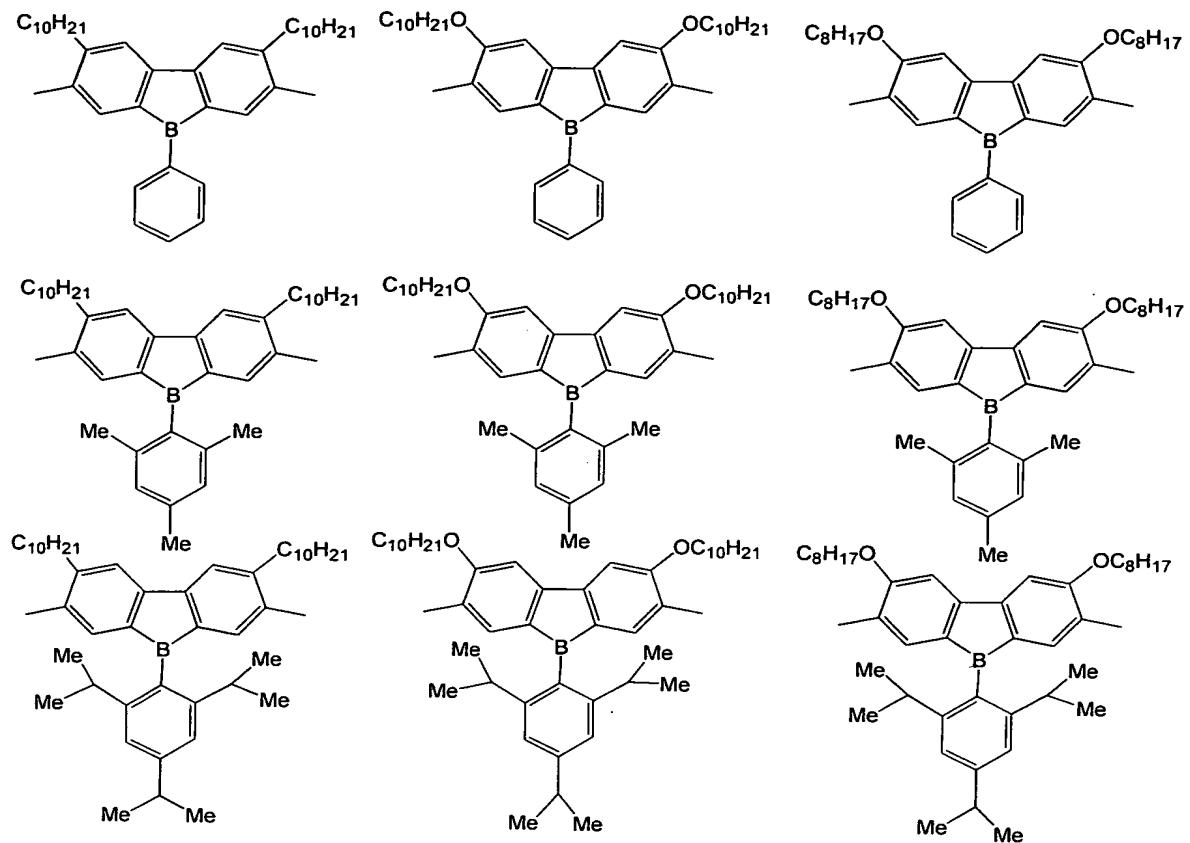


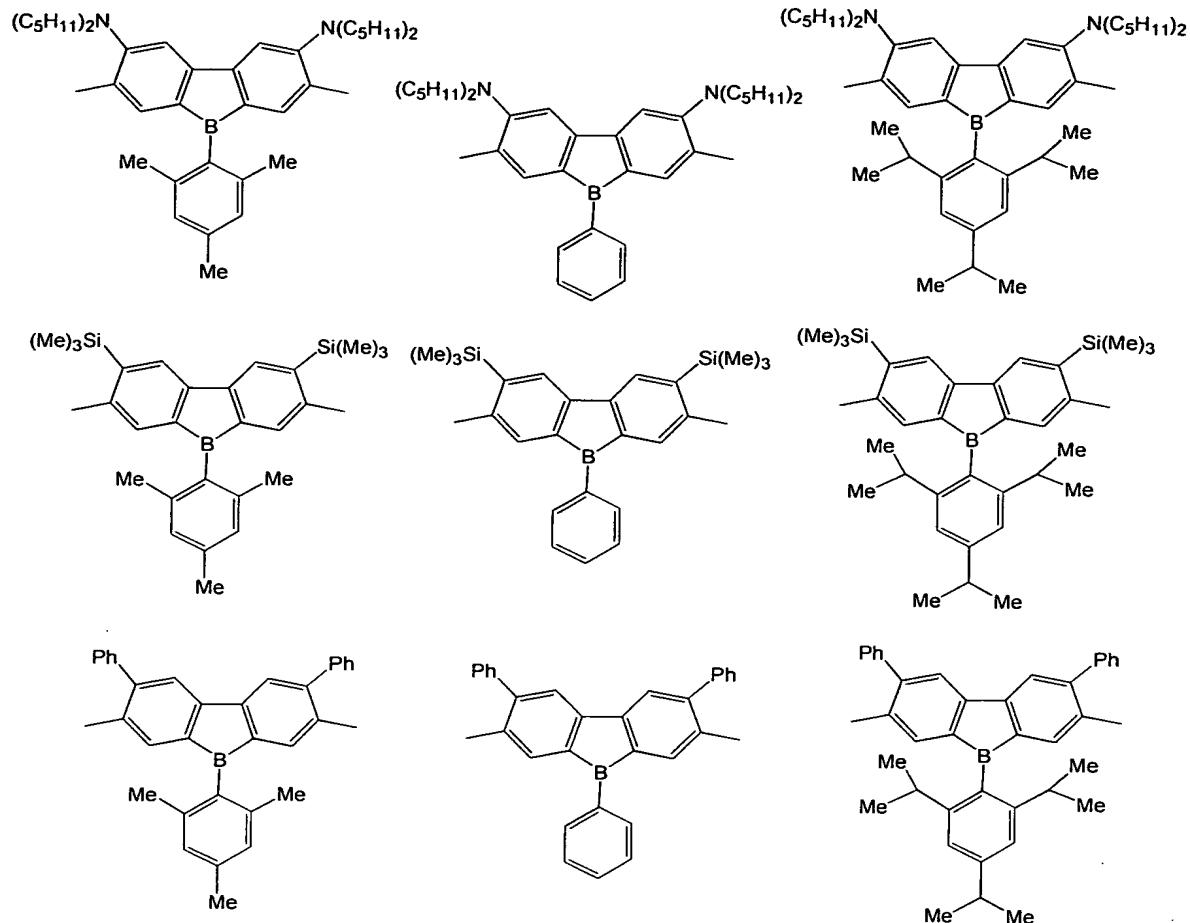


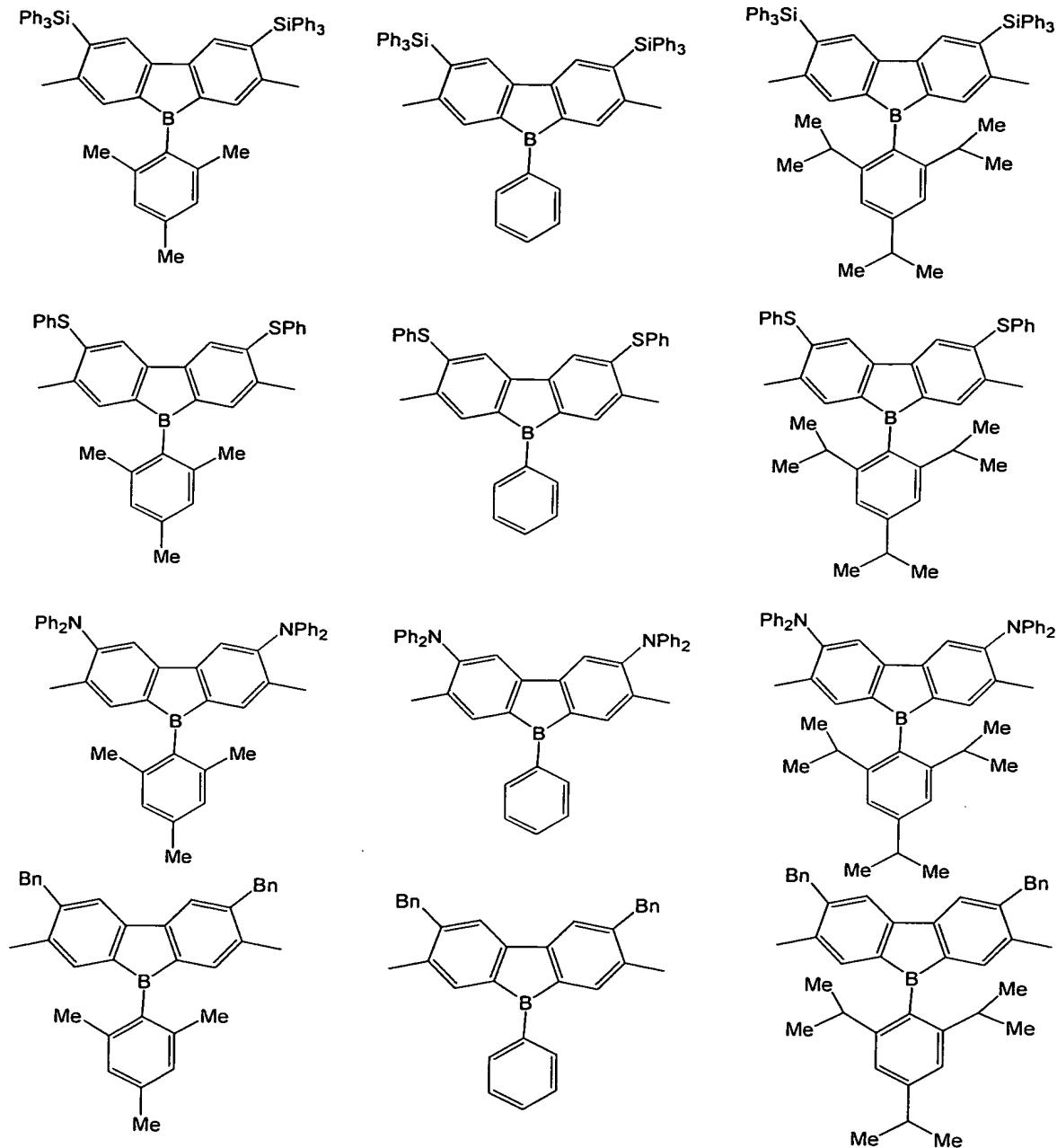


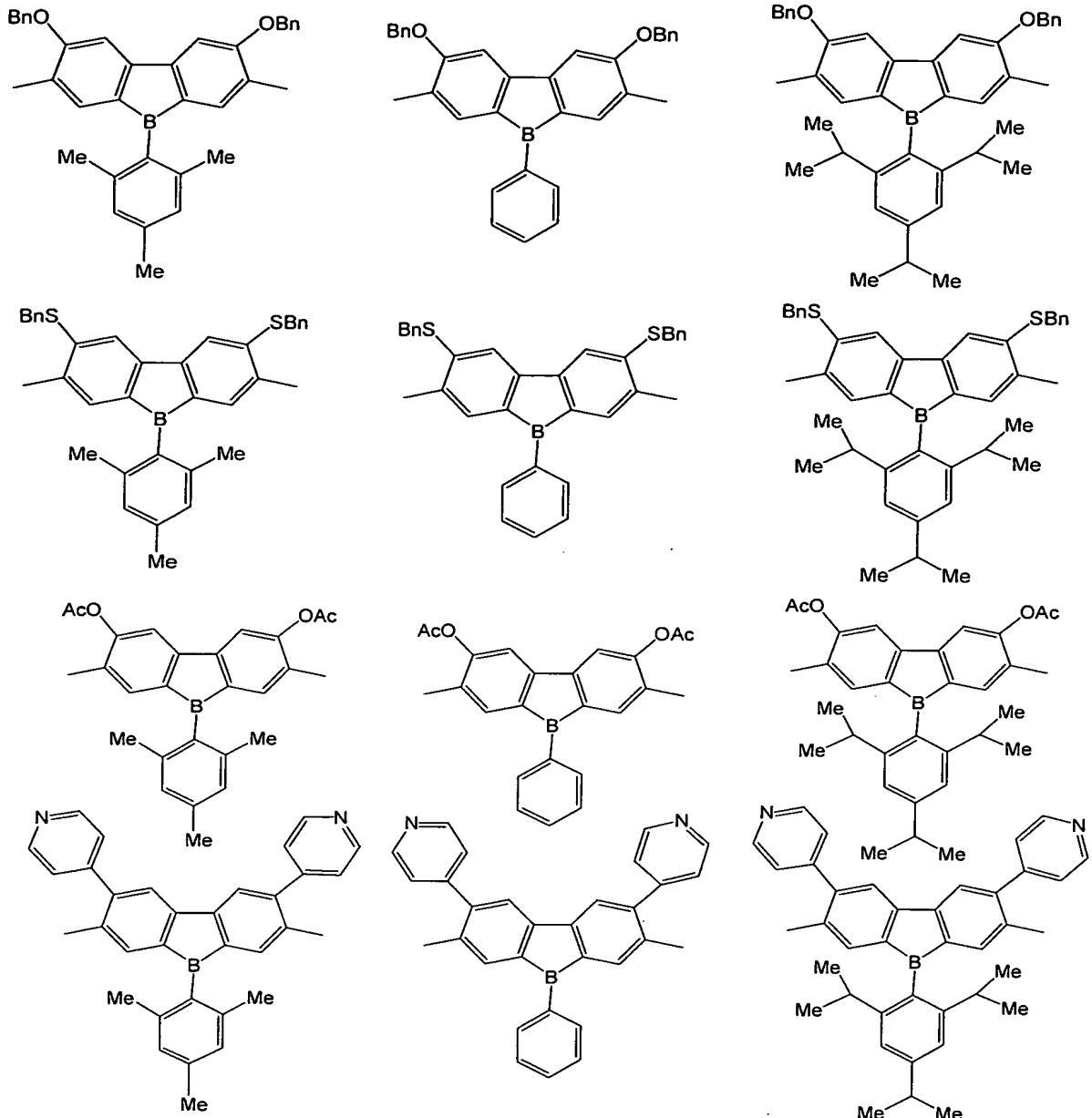
Specific examples of repeating units represented by the formula (1) include the following units.

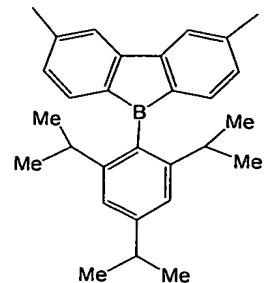
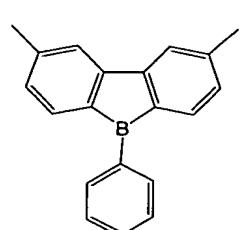
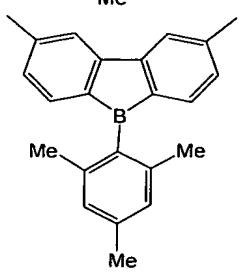
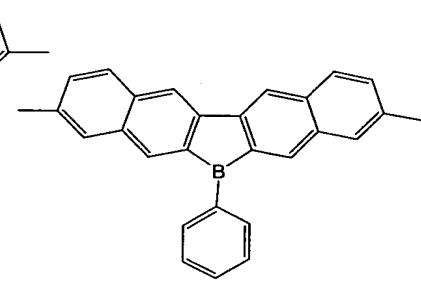
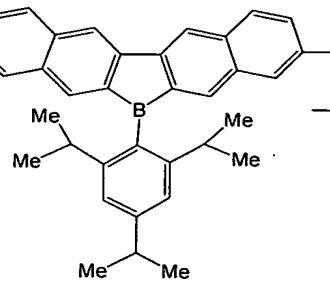
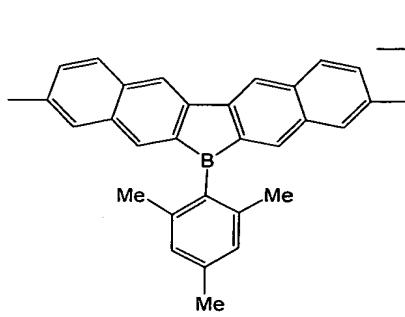
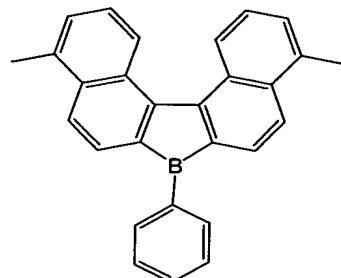
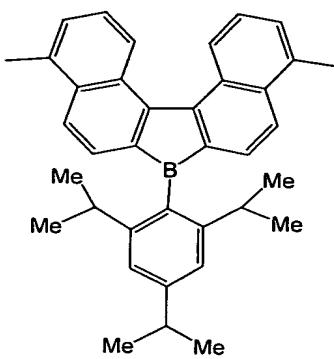
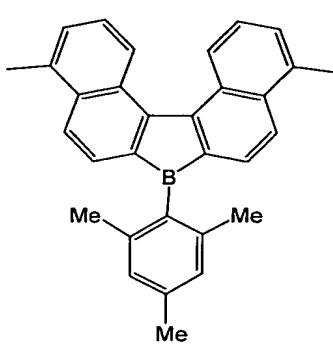
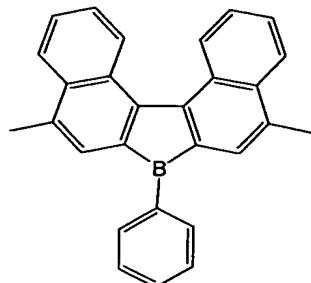
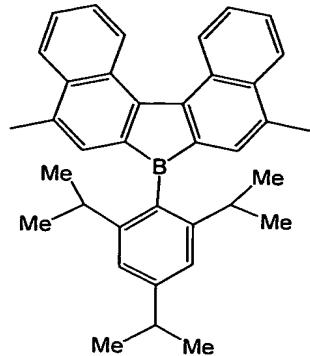
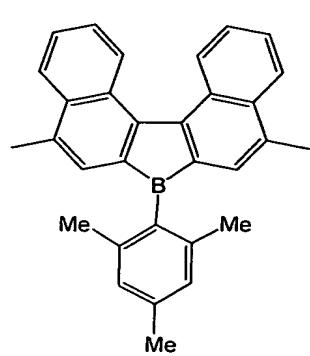


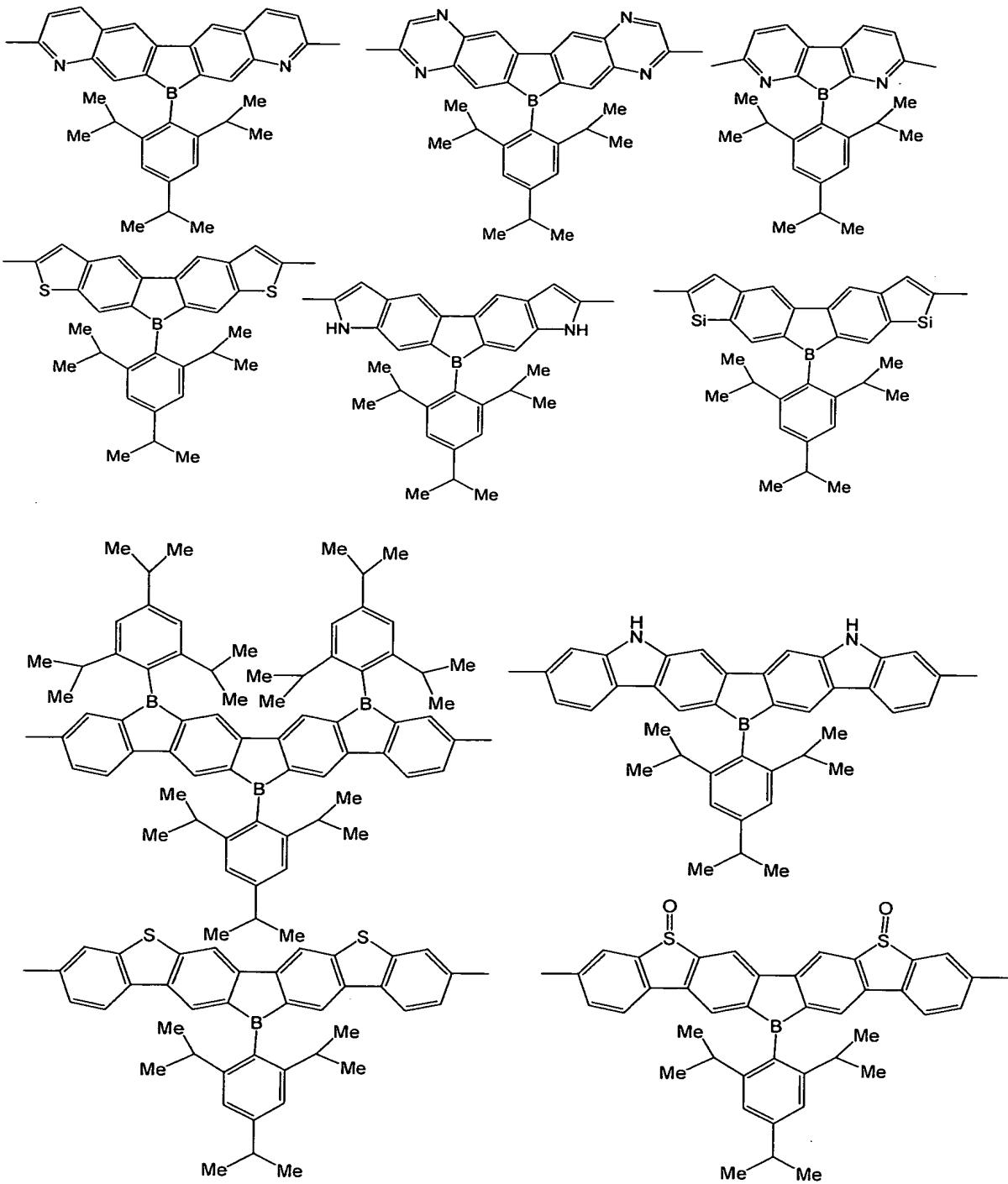


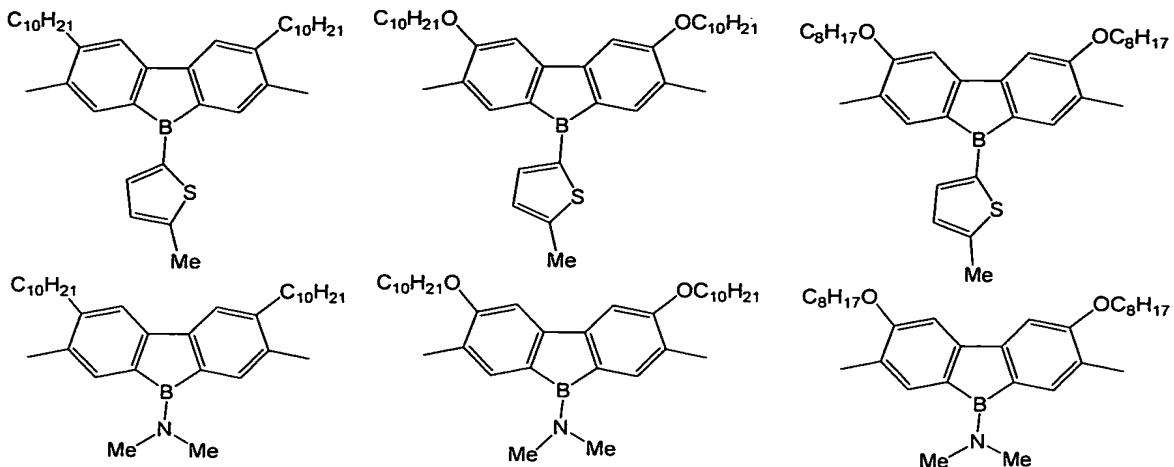












In the above formulae, Me represents a methyl group; Ph a phenyl group; Bn a benzyl group; and Ac an acetyl group.

In order to increase the polymer solubility,

5 shift the luminescence wavelength or increase the luminous efficiency, preferably the ring(s) D and/or E in the above formula (1) has a substituent selected from the group consisting of alkyl, alkoxy, alkylthio, aryl, aryloxy, arylthio, arylalkyl, arylalkoxy,

10 arylalkylthio, arylalkenyl, arylalkynyl, amino, substituted amino, silyl, substituted silyl, silyloxy and substituted silyloxy groups, halogen atoms, and acyl, acyloxy, imino, amide, imide, monovalent heterocyclic, carboxyl, substituted carboxyl and cyano

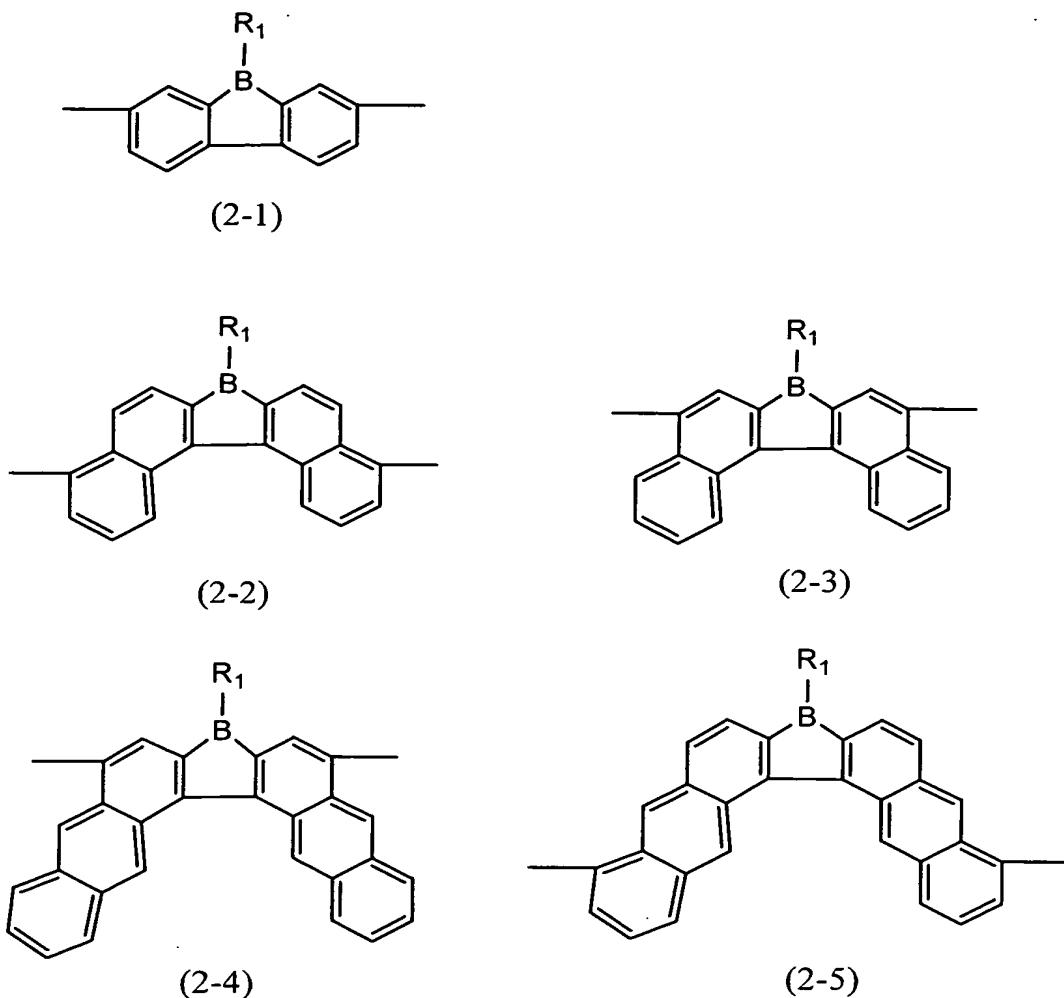
15 groups. More preferably, the substituent is selected from the group consisting of alkyl, alkoxy, alkylthio, aryl, aryloxy, arylthio, arylalkyl, arylalkoxy, arylalkylthio, amino, substituted amino, substituted silyl and substituted silyloxy groups, a fluorine atom,

and acyl, acyloxy, amide, imide, monovalent heterocyclic, carboxyl, substituted carboxyl and cyano groups. Much more preferably, the substituent is an alkyl, alkoxy, alkylthio, aryloxy, arylthio, arylalkyl, 5 arylalkoxy, arylalkylthio, amino or substituted amino group. Particularly preferably, the substituent is an alkyl, alkoxy, alkylthio or substituted amino group.

To increase the solubility of the polymer in a solvent, preferably R_1 in the formula (1) contains a 10 cyclic or branched alkyl chain. Also preferably, one or more of the substituents of the rings D and E contain a straight alkyl chain or a cyclic or branched alkyl chain having 3 or more carbon atoms.

The rings D and E are preferably aromatic 15 hydrocarbon rings, and more preferably benzene, naphthalene or anthracene rings.

Of the above described repeating units, those represented by the following formula (2-1), (2-2), (2-3), (2-4) or (2-5) are particularly preferable.

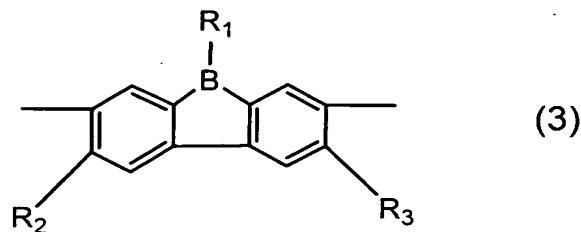


In order to increase the polymer solubility, shift the luminescence wavelength or increase the luminous efficiency, preferably the benzene, naphthalene or anthracene ring has one or more 5 substituents. Preferred substituents are the same as those contained in the ring(s) D and/or E in the above described formula (1). Preferably, one or more of the above substituents contain a straight alkyl chain or a cyclic or branched alkyl chain having 3 or more carbon

atoms.

In the formula (2-1), (2-2), (2-3), (2-4) or (2-5), R₁ represents the same group as in the formula (1).

5 Of the above described repeating units, those represented by the formula (2-1) are more preferable and those represented by the following formula (3) are particularly preferable.



In the above formula, R₁ represents the same group as in
10 the formula (1); and R₂ and R₃ each independently represent an alkyl, alkoxy, alkylthio, aryloxy, arylthio, arylalkyl, arylalkoxy, arylalkylthio, amino or substituted amino group.

15 Preferably, each of R₂ and R₃ is an alkyl, alkoxy, alkylthio or substituted amino group.

In the repeating units represented by the above formulae (1), (2-1) to (2-5) and (3), preferably R₁ is an alkyl, aryl, substituted amino or monovalent heterocyclic group and more preferably an aryl, substituted amino or monovalent heterocyclic group. Particularly preferably R₁ is a phenyl group having an alkyl group at each of 2, 4, 6 positions, a

dialkylamino group, or a thienyl group.

In the polymer in accordance with this invention, the amount of the repeating units represented by the formula (1) is usually 1 to 100% by 5 mole and preferably 20 to 90% by mole of the total amount of the repeating units the polymer has.

In order to increase the intensity of fluorescence, preferably the polymer in accordance with this invention is a copolymer of the repeating units 10 represented by the formula (1) and each having different substituents or a copolymer of the repeating units represented by the formula (1) and at least one or more kinds of repeating units other than those represented by the formula (1). Preferably the 15 repeating units, other than those represented by the formula (1), which the polymer of this invention may contain is represented by the following formula (4), (5), (6) or (7).

	-Ar ₁ -	(4)
20	-Ar ₁ -X ₁ -(Ar ₂ -X ₂) _w -Ar ₃ -	(5)
	-Ar ₁ -X ₂ -	(6)
	-X ₂ -	(7)

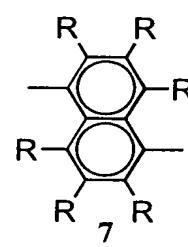
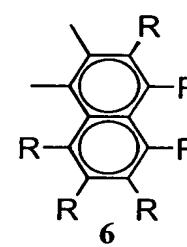
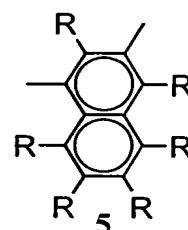
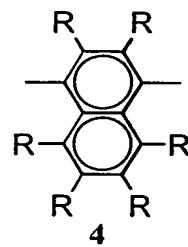
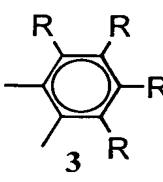
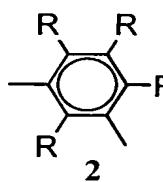
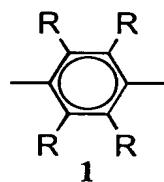
In the above formulae, Ar₁, Ar₂ and Ar₃ each independently represent an arylene group, a divalent 25 heterocyclic group or a divalent group having a metal complex structure. X₁ represents -C≡C-, -N(R₂₂)- or -(SiR₂₃R₂₄)_y-. X₂ represents -CR₂₀=CR₂₁-, -C≡C-, -N(R₂₂)- or -(SiR₂₃R₂₄)_y-. R₂₀ and R₂₁ each independently

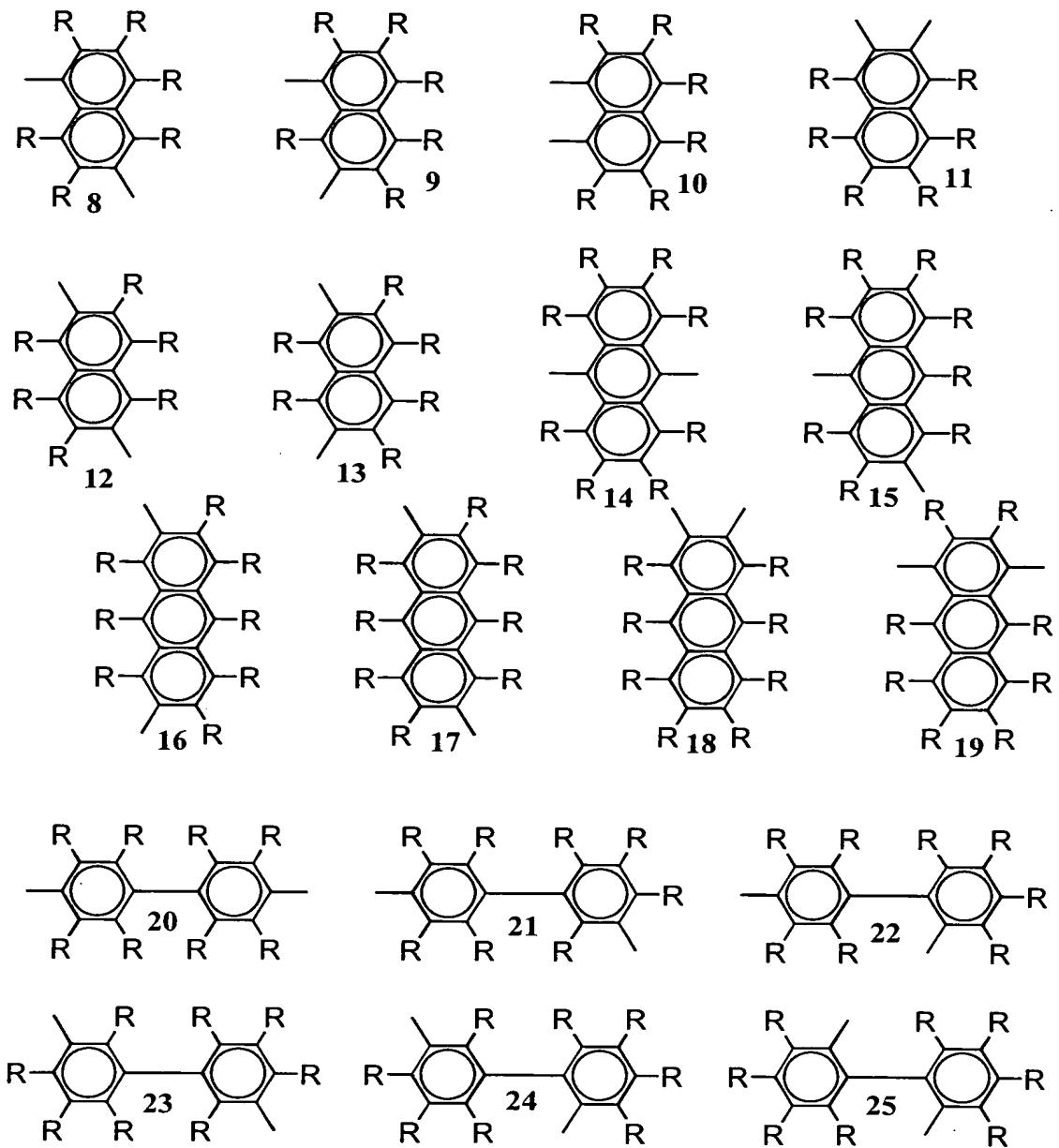
represent a hydrogen atom, or alkyl, aryl, monovalent heterocyclic, carboxyl, substituted carboxyl or cyano group. R₂₂, R₂₃ and R₂₄ each independently represent a hydrogen atom, or alkyl, aryl, monovalent heterocyclic 5 or arylalkyl group. w represents an integer of 0 to 1. y represents an integer of 1 to 12.

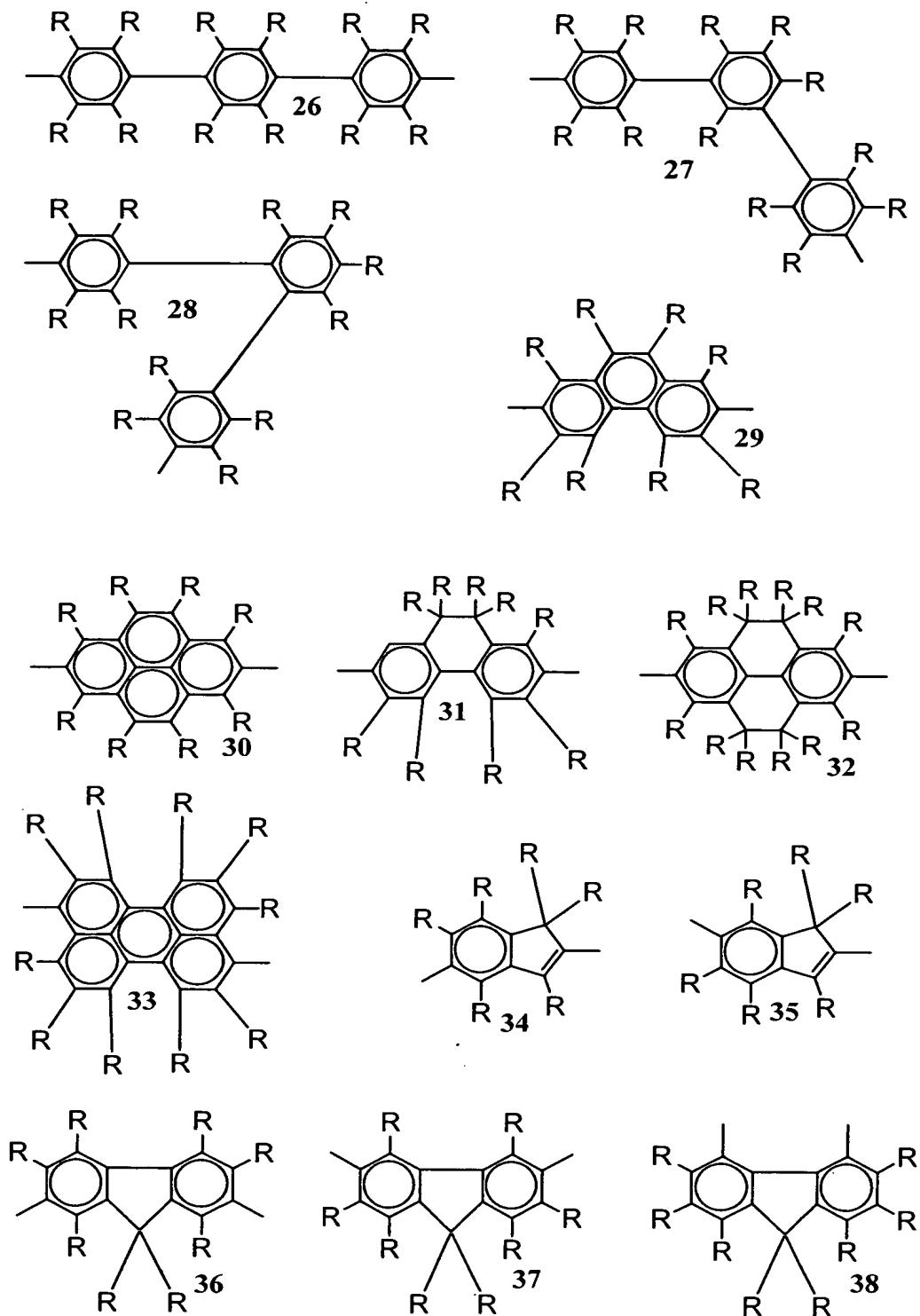
The term "arylene group" means an atomic group formed by removal of two hydrogen atoms on the ring of an aromatic hydrocarbon. The above described 10 arylene groups include those having a condensed ring and those formed by combining two or more independent benzene rings or condensed rings directly or via a group such as vinylene. The number of carbons that each of the arylene groups has is usually about 6 to 60 15 and preferably about 6 to 20. The arylene groups optionally have a substituent. Examples of such substituents include alkyl, alkoxy, alkylthio, aryl, aryloxy, arylthio, arylalkyl, arylalkoxy, arylalkylthio, arylalkenyl, arylalkynyl, amino, 20 substituted amino, silyl, substituted silyl, silyloxy and substituted silyloxy groups, halogen atoms, and acyl, acyloxy, imino, amide, imide, monovalent heterocyclic, carboxyl, substituted carboxyl and cyano groups. Preferably, the substituent is alkyl, alkoxy, 25 alkylthio, aryl, aryloxy, arylthio, substituted amino, substituted silyl, substituted silyloxy or monovalent heterocyclic group.

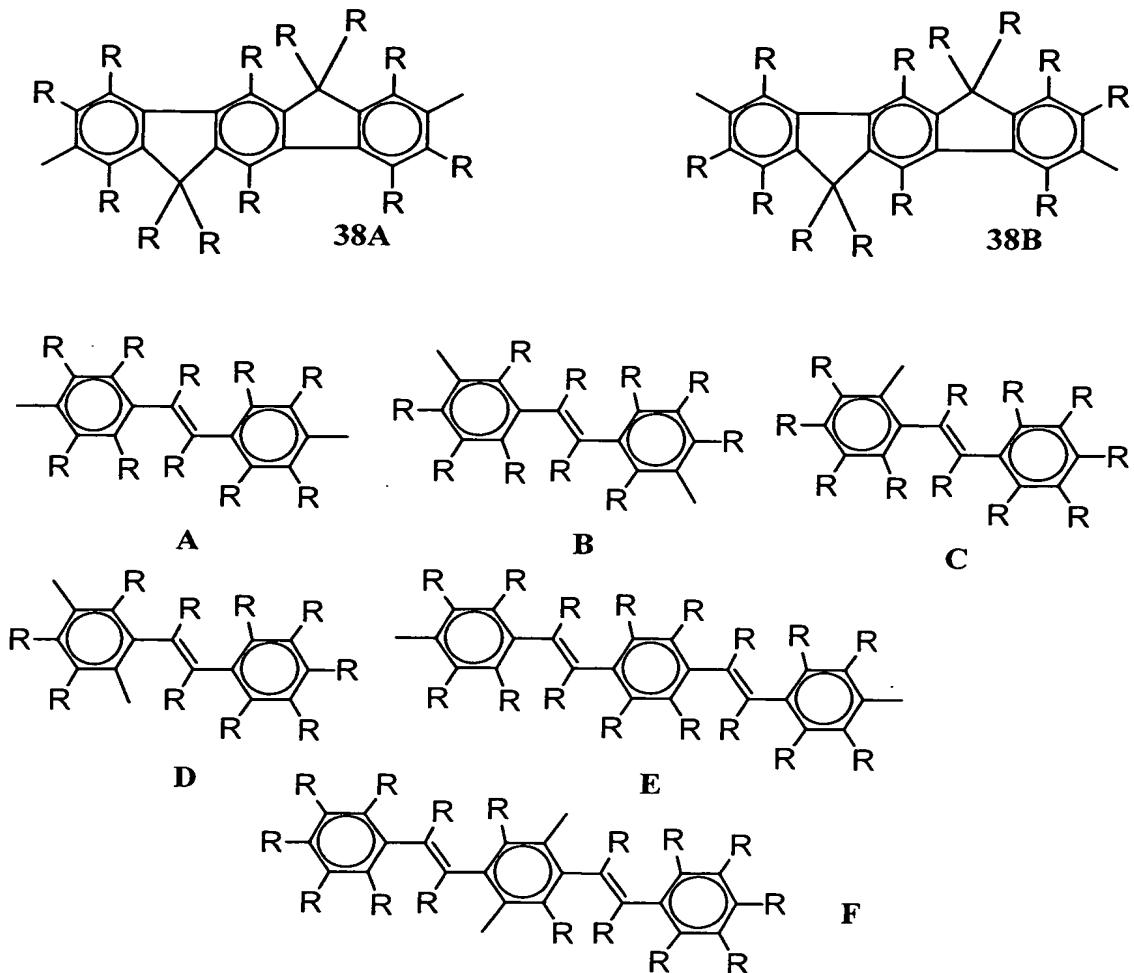
Examples of arylene groups include a

phenylene group (e.g. formulae 1 to 3 below), a naphthalenediyl group (e.g. formulae 4 to 13 below), anthracenediyl (e.g. formulae 14 to 19 below), a biphenyldiyl group (e.g. formulae 20 to 25 below), a 5 terphenyldiyl group (e.g. formulae 26 to 28 below), condensed ring compounds (e.g. formulae 29 to 35 below), a fluorenediyl group (e.g. formulae 36 to 38 below), an indenofluorenediyl group (e.g. formulae 38A to 38B below), a stilbenediyl group (e.g. formulae A to 10 D below), and a distilbenediyl group (e.g. formulae E and F below). Of these arylene groups, preferable are phenylene, biphenyldiyl, fluorenediyl and stilbenediyl groups.









In this invention, the term "divalent heterocyclic group" means an atomic group formed by removal of two hydrogen atoms on the ring of a heterocyclic compound. The number of carbons that each 5 of the divalent heterocyclic groups has is usually about 3 to 60 and preferably 4 to 20. The divalent heterocyclic groups optionally have a substituent.

The term "heterocyclic compound" means an organic compound having a ring structure in which the 10 ring structure is composed of not only carbon atoms,

but also a heteroatom(s) such as oxygen, sulfur, nitrogen, phosphorus, boron and arsenic.

Examples of the substituents the divalent heterocyclic groups have include alkyl, alkoxy, 5 alkylthio, aryl, aryloxy, arylthio, arylalkyl, arylalkoxy, arylalkylthio, arylalkenyl, arylalkynyl, amino, substituted amino, silyl, substituted silyl, silyloxy and substituted silyloxy groups, halogen atoms, and acyl, acyloxy, imino, amide, imide, 10 monovalent heterocyclic, carboxyl, substituted carboxyl and cyano groups. Preferably, the substituent is alkyl, alkoxy, alkylthio, aryl, aryloxy, arylthio, substituted amino, substituted silyl, substituted silyloxy or monovalent heterocyclic group.

15 Examples of the divalent heterocyclic groups are as follows:

divalent heterocyclic groups containing nitrogen as a heteroatom(s) such as pyridinediyl (formulae 39 to 44 below), diazaphenylene (formulae 45 20 to 48 below), quinolinediyl (formulae 49 to 63 below), quinoxalinediyl (formulae 64 to 68 below), acridinediyl (formulae 69 to 72 below), bipyridylyl (formulae 73 to 75 below) and phenanthrolinediyl (formulae 76 to 78 below) groups;

25 divalent heterocyclic groups containing silicon, nitrogen, sulfur or selenium as a heteroatom(s) and having a fluorene structure (formulae 79 to 93 below);

divalent heterocyclic groups containing silicon, nitrogen, sulfur or selenium as a heteroatom(s) and having an indenofluorene structure (formulae J to O below);

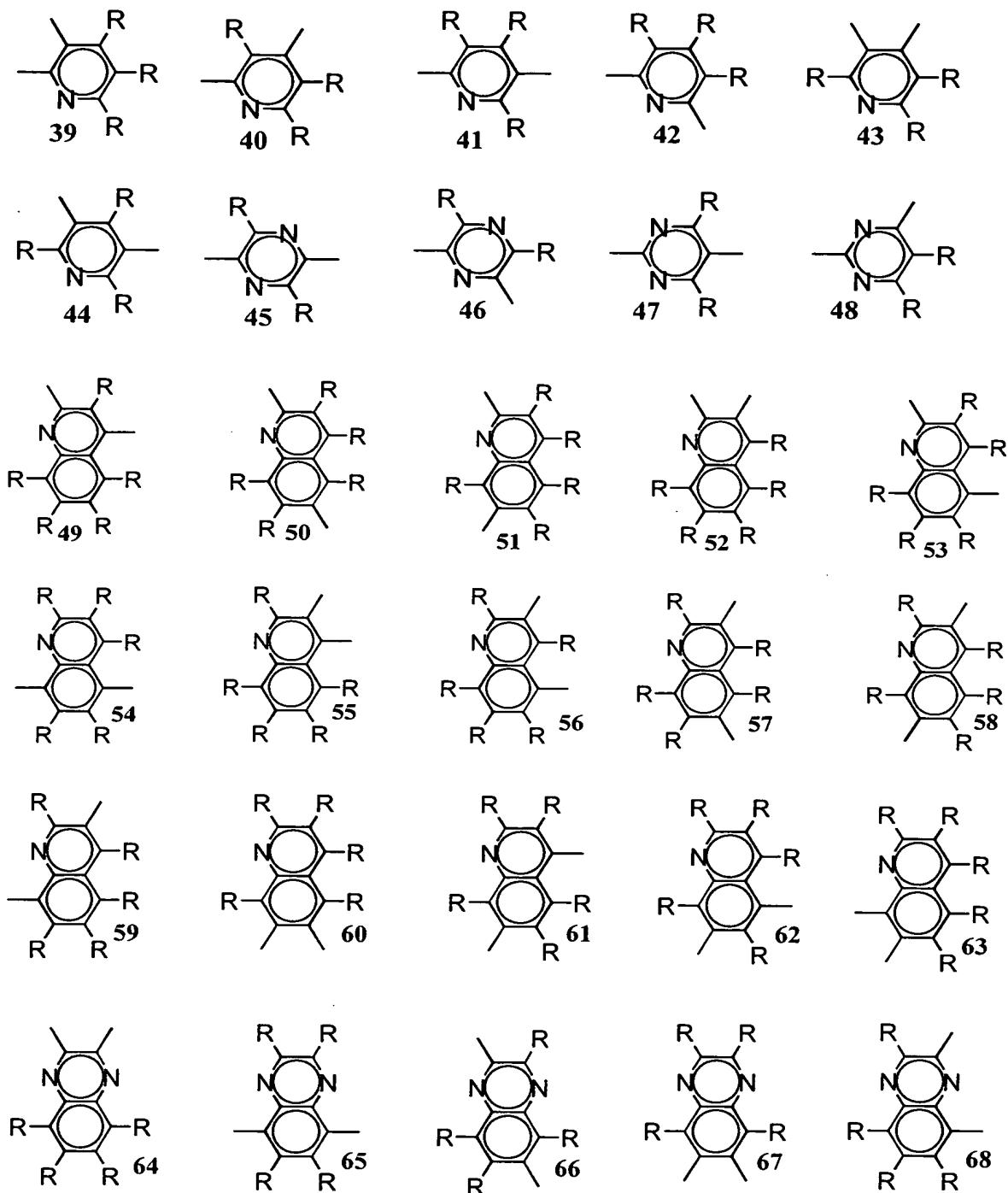
5 five-membered heterocyclic groups containing silicon, nitrogen, sulfur or selenium as a heteroatom(s) (formulae 94 to 98 below);

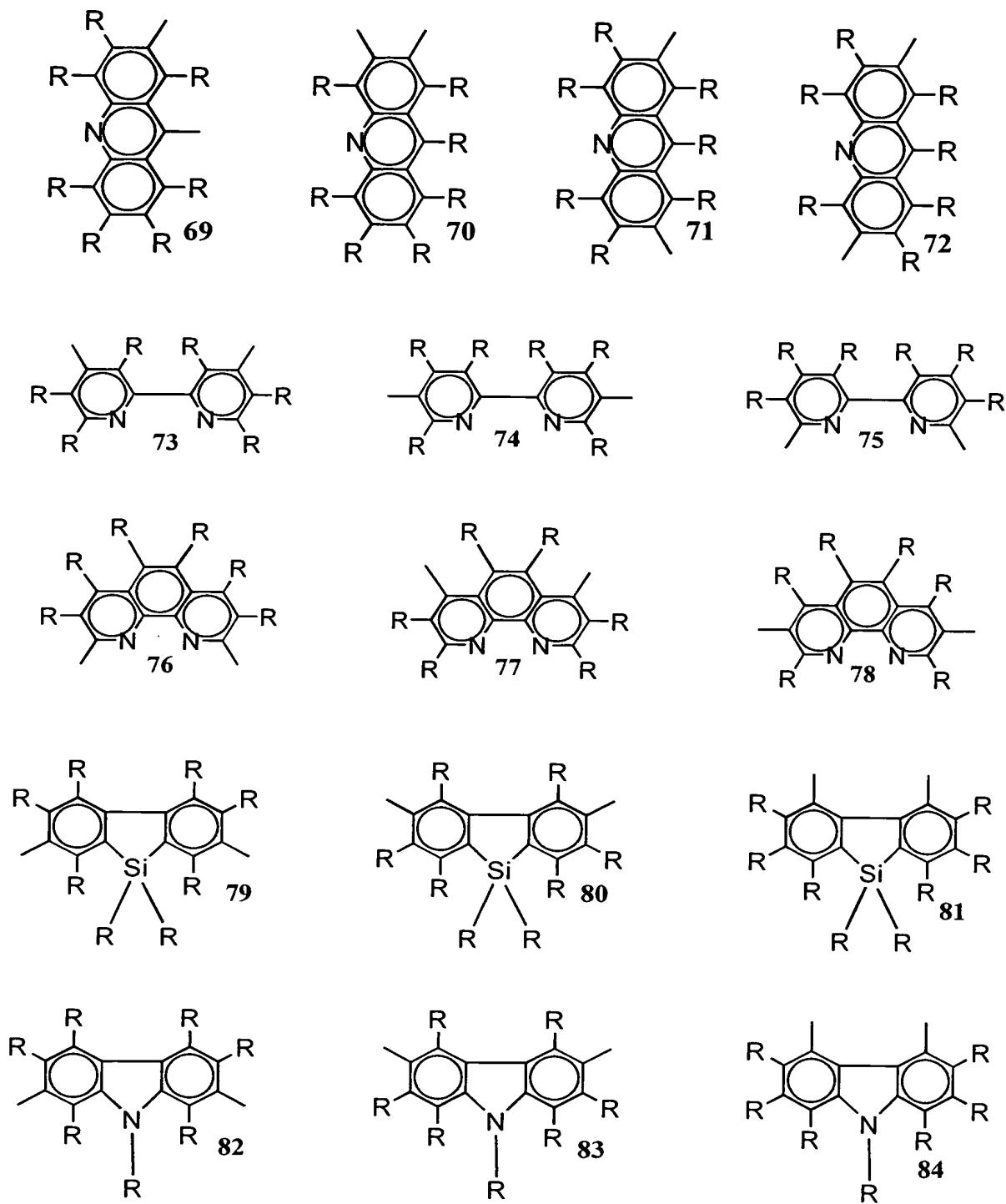
 five-membered ring condensed heterocyclic groups containing silicon, nitrogen, sulfur or selenium 10 as a heteroatom(s) (formulae 99 to 110 below);

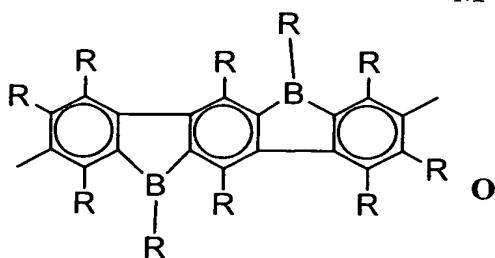
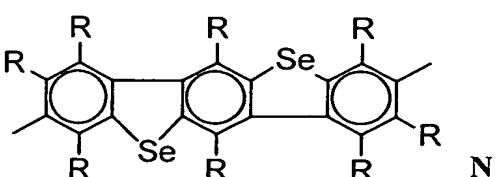
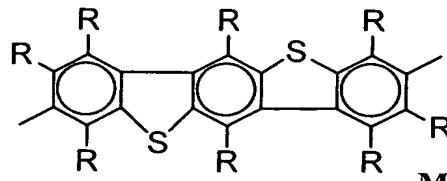
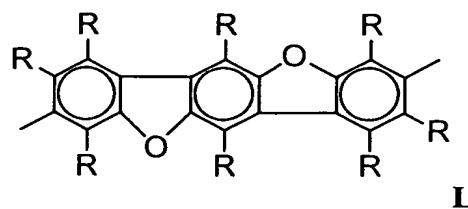
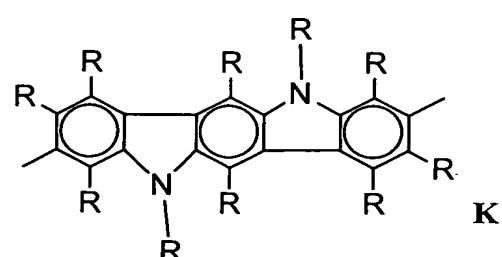
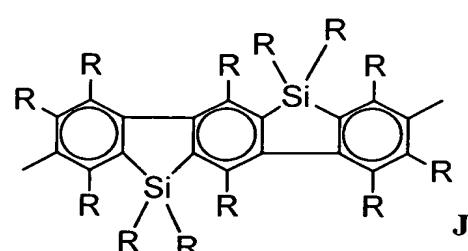
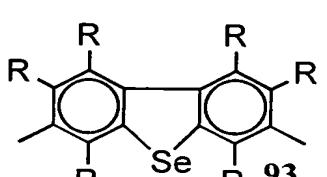
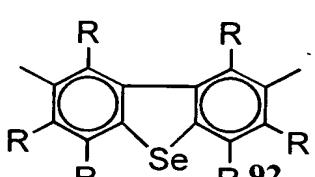
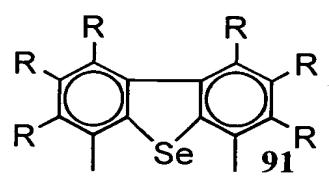
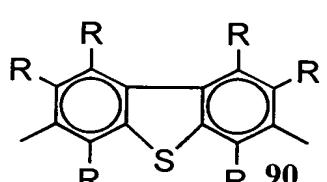
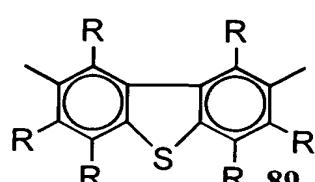
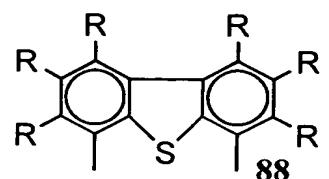
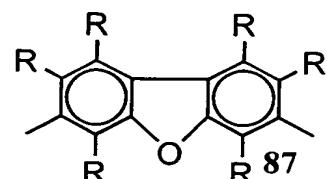
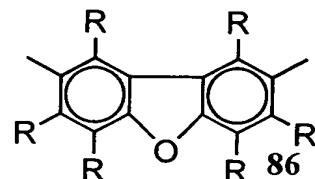
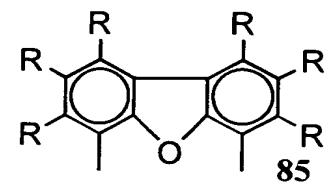
 five-membered heterocyclic groups containing silicon, nitrogen, sulfur or selenium as a heteroatom(s) two or more of which are combined at 15 their α positions to form a dimer or oligomer (formulae 111 to 112 below);

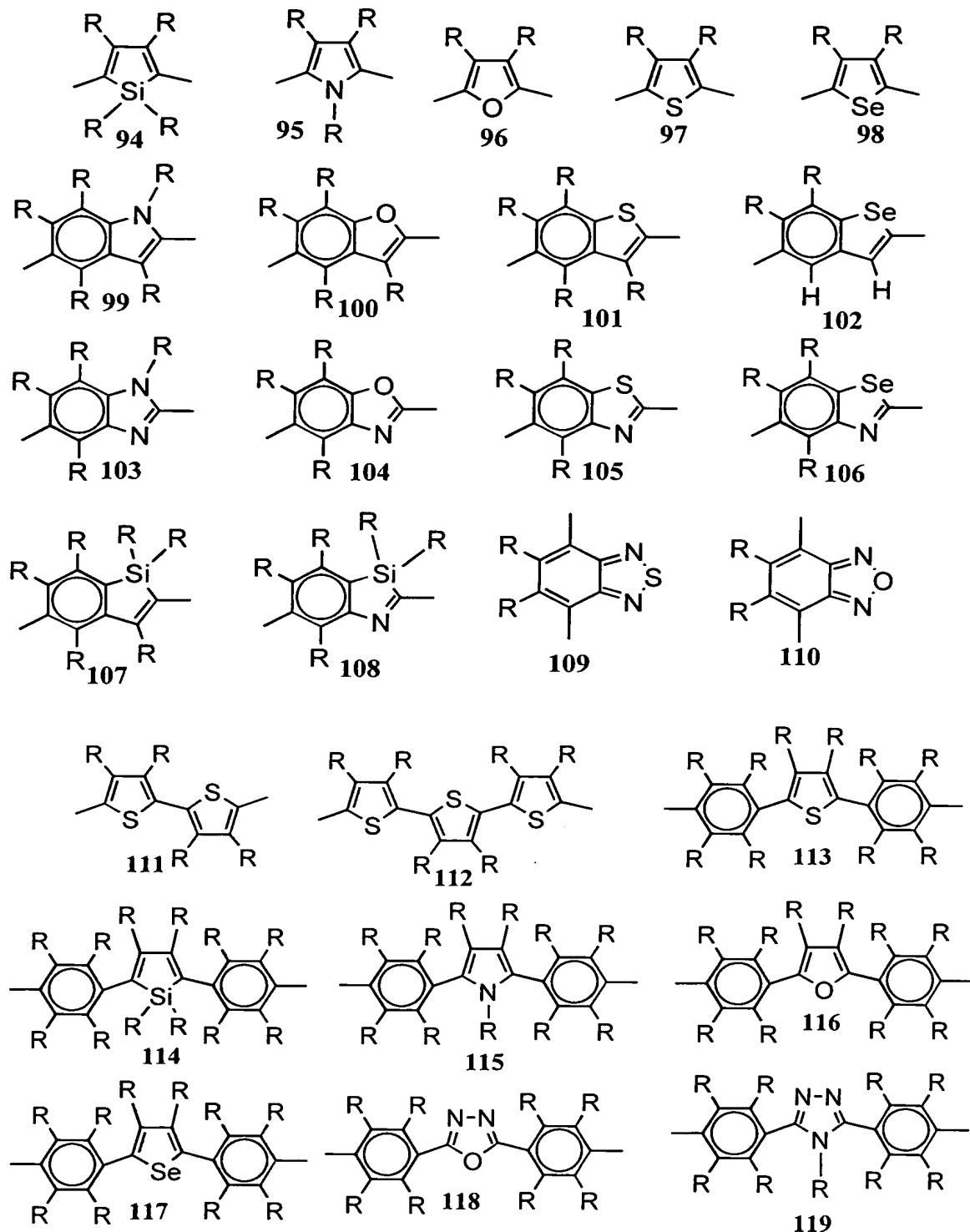
 five-membered heterocyclic groups containing silicon, nitrogen, sulfur or selenium as a heteroatom(s) which are combined with phenyl groups at their α positions (formulae 113 to 119 below); and

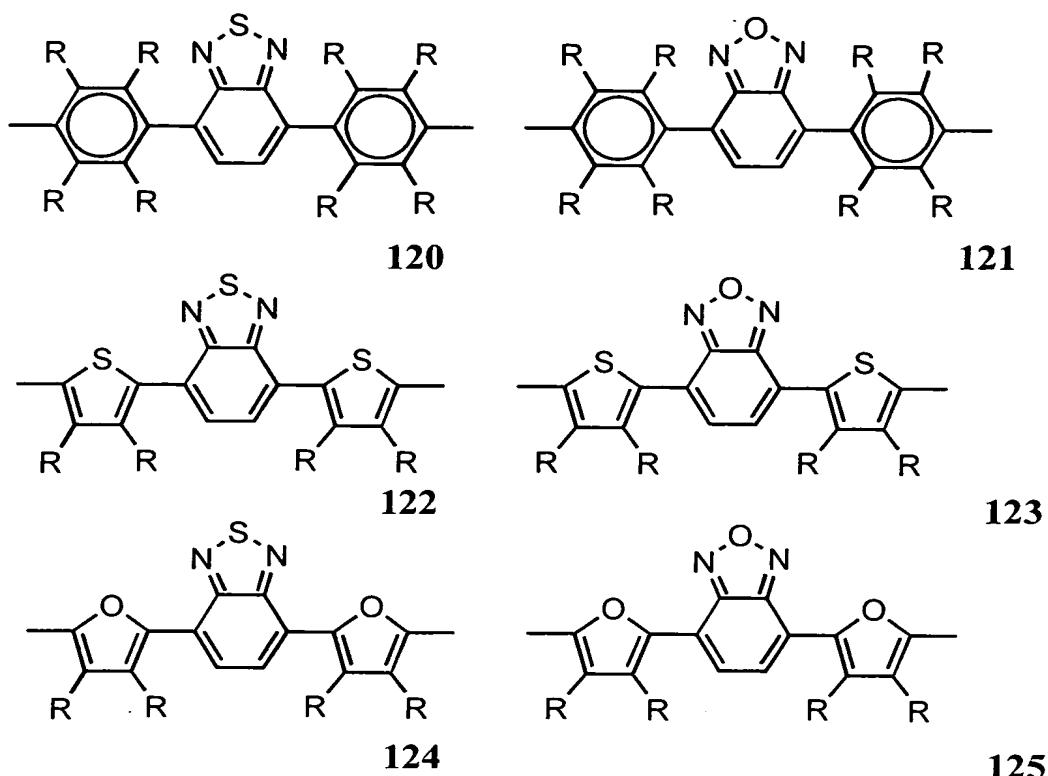
20 five-membered ring condensed heterocyclic groups containing oxygen, nitrogen or sulfur as a heteroatom(s) and substituted by phenyl, furil or thiienyl groups (formulae 120 to 125 below).











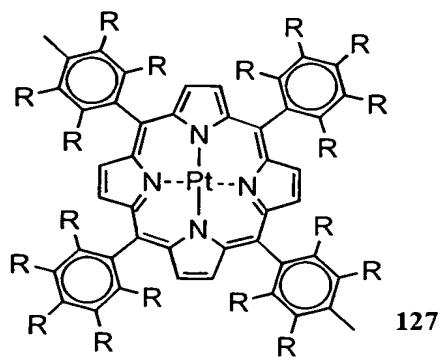
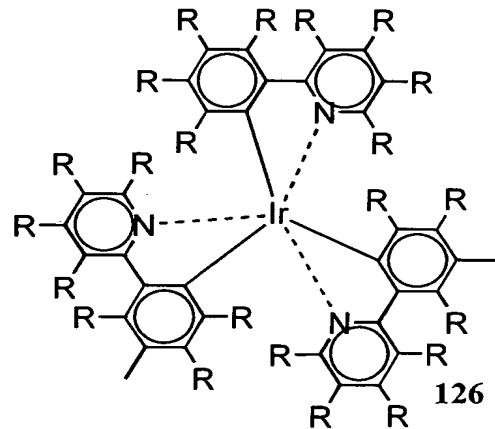
The term "divalent group having a metal complex structure" means a divalent group derived from a metal complex having an organic ligand by removal of two hydrogen atoms on the ligand.

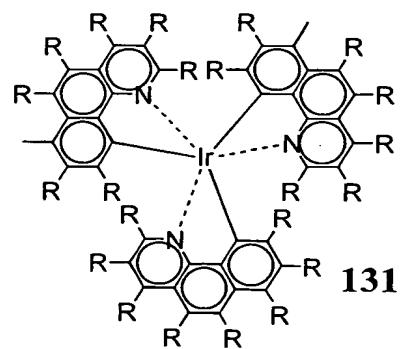
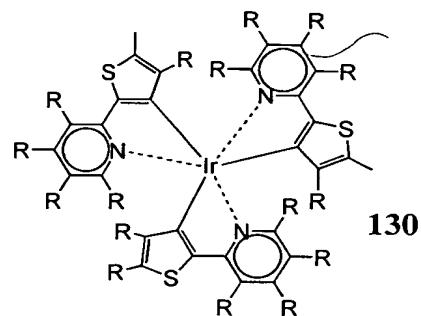
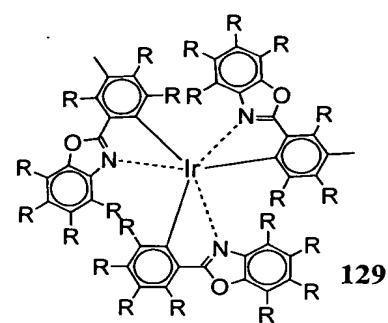
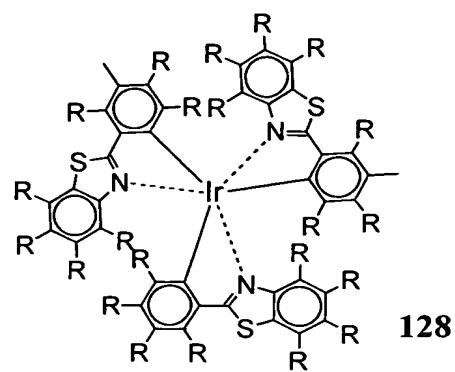
5 In metal complexes having an organic ligand,
the number of carbons that each of the organic ligands
has is usually about 4 to 60. Examples of such organic
ligands include 8-quinolinol and the derivatives
thereof, benzoquinolinol and the derivatives thereof,
10 2-phenyl-pyridine and the derivatives thereof, 2-
phenyl-benzothiazole and the derivatives thereof, 2-
phenyl-benzoxazole and the derivatives thereof, and
porphine and the derivatives thereof.

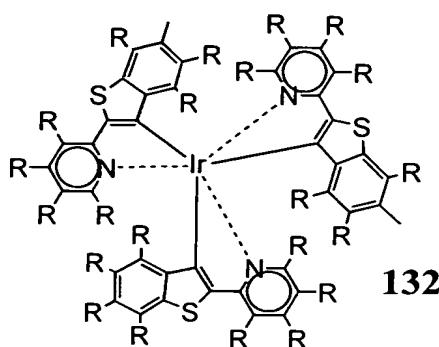
Examples of central metal atoms of metal complexes having an organic ligand include aluminum, zinc, beryllium, iridium, platinum, gold, europium and terbium.

5 Examples of metal complexes having an organic ligand include those known as low-molecule fluorescent materials or phosphorescent materials and so-called triplet luminescent complexes.

10 Examples of divalent groups having a metal complex structure include the following groups (formulae 126 to 132).







In the above described formulae 1 to 132 and G to O, R each independently represents a hydrogen atom, or an alkyl, alkoxy, alkylthio, aryl, aryloxy, arylthio, arylalkyl, arylalkoxy, arylalkylthio, 5 arylalkenyl, arylalkynyl, amino, substituted amino, silyl, substituted silyl, silyloxy or substituted silyloxy group, or a halogen atom, or an acyl, acyloxy, imino, amide, imide, monovalent heterocyclic, carboxyl, substituted carboxyl or cyano group.

10 Although a single structural formula has a plurality of Rs in the above described examples, they may represent the same group or atom or different groups or atoms. To increase the solubility of the polymer in a solvent, it is preferable that at least 15 one of the Rs in a single structural formula is other than hydrogen, and besides the shape of repeating units, including their substituents, does not have a large degree of symmetry. It is also preferable that one or more of the Rs in a single structural formula 20 are groups that contain a straight-chain alkyl group or

a cyclic or branched-chain alkyl group having 3 or more carbon atoms. A plurality of Rs may be linked together to form a ring.

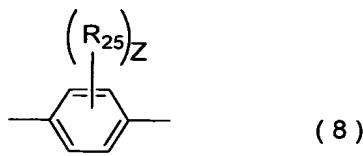
In the substituents of the above described formulae in which at least one R contains an alkyl group, the alkyl group may be a straight-chain, branched-chain or cyclic alkyl group, or a combination thereof. When the alkyl group is not a straight-chain one, it may be an isoamyl, 2-ethylhexyl, 3,7-dimethyloctyl, cyclohexyl or 4-(C1-C12)-alkylcyclohexyl group.

Further, the methyl or methylene group of the alkyl group contained in at least one R of the substituents may be replaced by a methyl or methylene group substituted by a heteroatom or one or more fluorine atoms. Examples of such heteroatoms include oxygen, sulfur and nitrogen atoms.

When the R includes an aryl or heterocyclic group as its part, the aryl or heterocyclic group may further include one or more substituents.

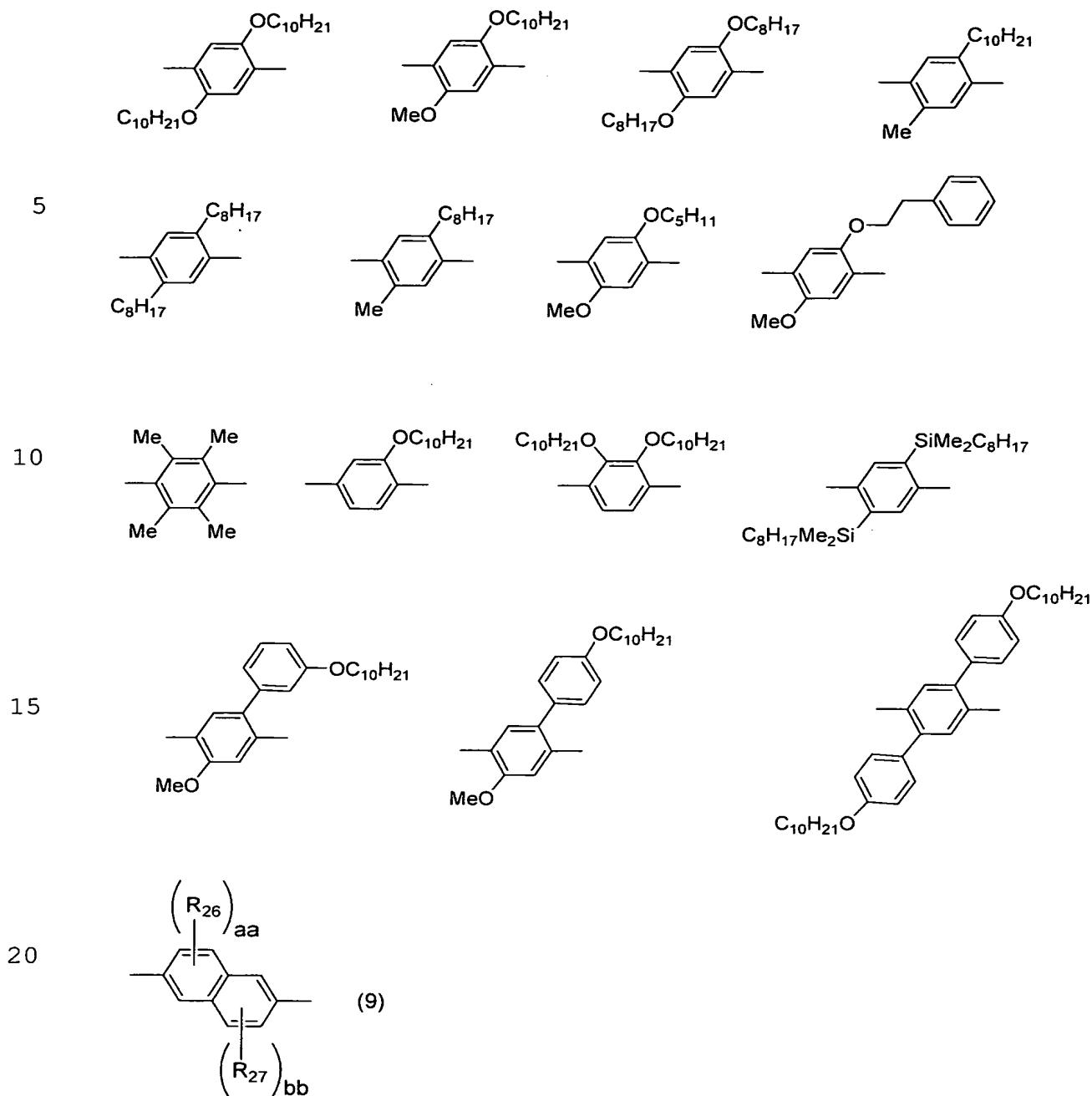
Of the repeating units, other than those represented by the formula (1), which the polymer of this invention may contain, those represented by the above formulae (4) and (5) are more preferable.

Of the repeating units represented by the above formula (4), those represented by the following formula (8), (9), (10), (11), (12) or (13) are preferable.



In the above formula, R_{25} represents an alkyl, alkoxy, alkylthio, aryl, aryloxy, arylthio, arylalkyl, arylalkoxy, arylalkylthio, arylalkenyl, arylalkynyl, amino, substituted amino, silyl, substituted silyl, 5 silyloxy or substituted silyloxy group, or a halogen atom, or an acyl, acyloxy, imino, amide, imide, monovalent heterocyclic, carboxyl, substituted carboxyl or cyano group; and z represents an integer of 0 to 4. When more than one group or atom R_{25} exist, they may be 10 the same or different.

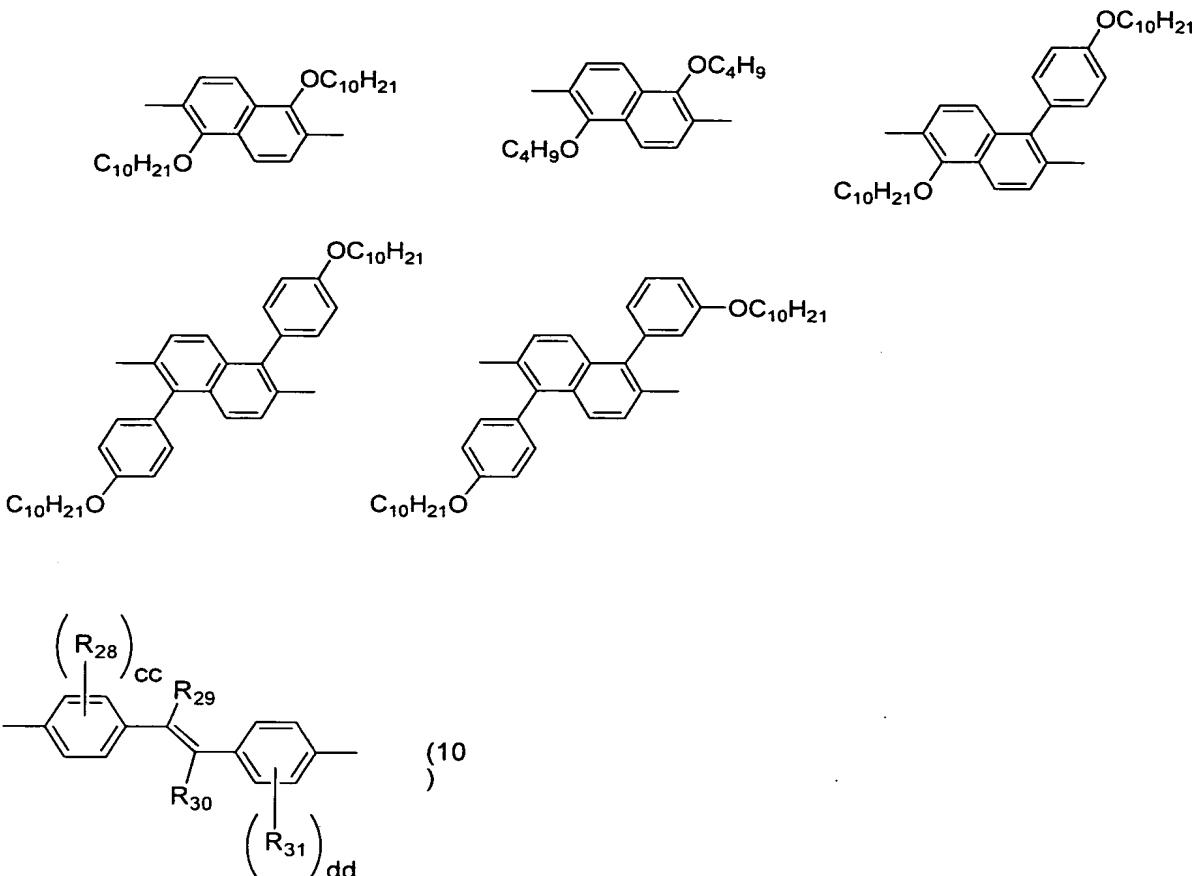
Specific examples of the repeating units represented by the formula (8) are as follows.



In the above formula, R_{26} and R_{27} each independently
 25 represent the same group as the R_{25} in the formula (8);
 and aa and bb each independently represent an integer
 of 0 to 3. When more than one group or atom R_{26} and
 more than one group or atom R_{27} exist, they may be the

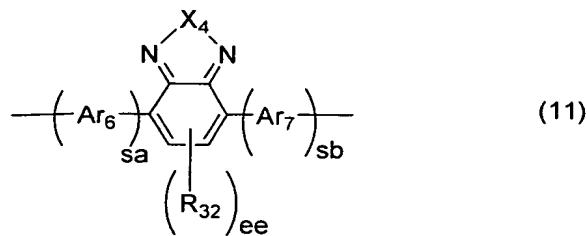
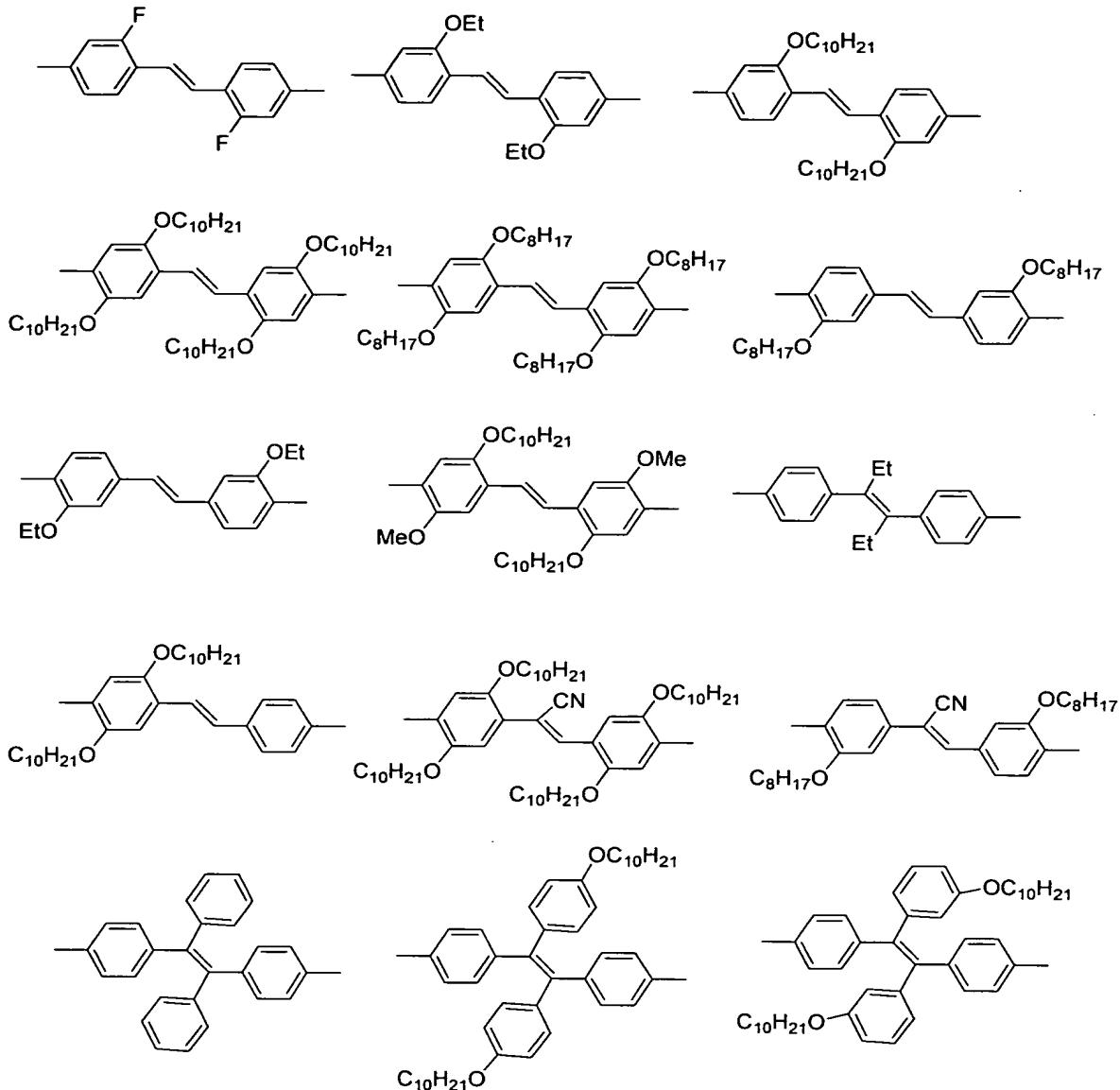
same or different.

Specific examples of the repeating units represented by the formula (9) are as follows.



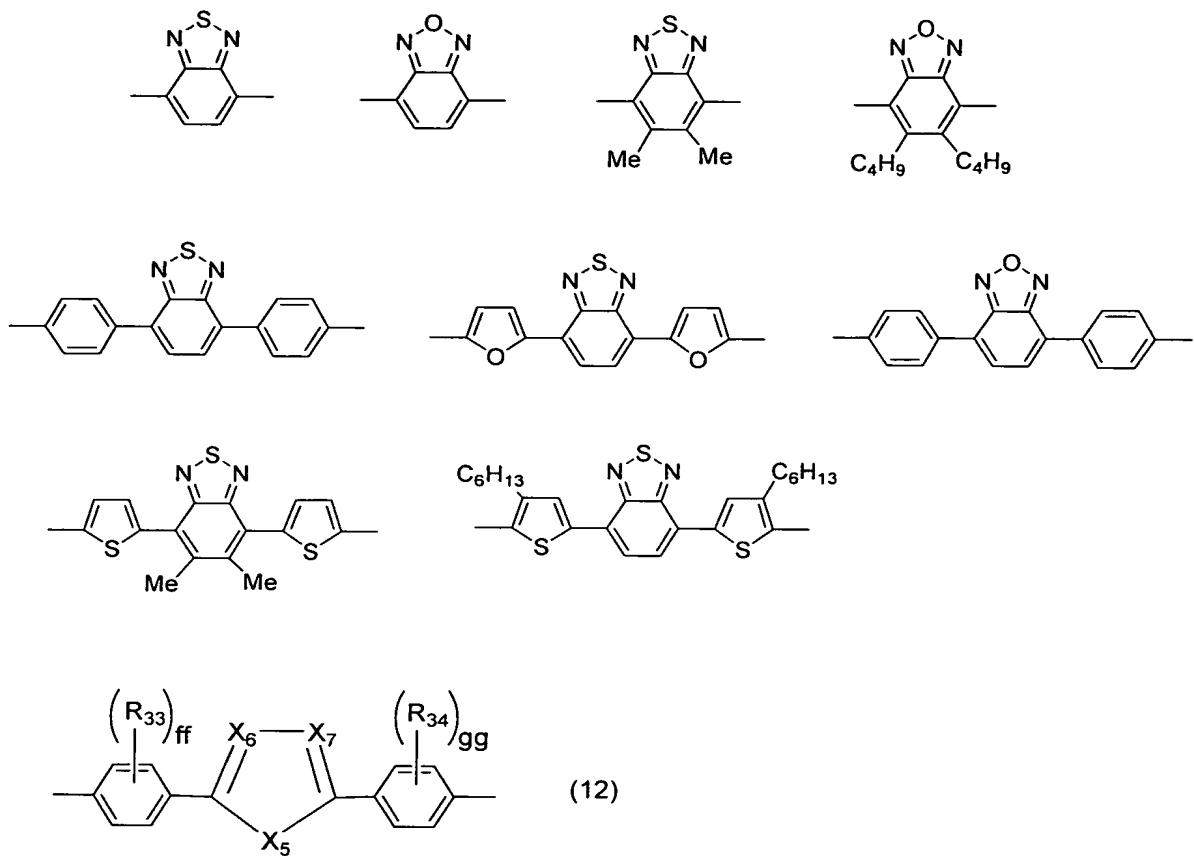
In the above formula, R_{28} and R_{31} each independently
 5 represent the same group as the R_{25} in the formula (8);
 cc and dd each independently represent an integer of 0
 to 4; and R_{29} and R_{30} each independently represent a
 hydrogen atom, or an alkyl, aryl, monovalent
 heterocyclic, carboxyl, substituted carboxyl or cyano
 10 group. When more than one atom or group R_{28} and more
 than one atom or group R_{31} exist, they may be the same
 or different.

Specific examples of the repeating units represented by the formula (10) are as follows.



In the above formula, R_{32} represents an alkyl, alkoxy, alkylthio, aryl, aryloxy, arylthio, arylalkyl, arylalkoxy, arylalkylthio, arylalkenyl, arylalkynyl, amino, substituted amino, silyl or substituted silyl group, or a halogen atom, or an acyl, acyloxy, imino, amide, imide, monovalent heterocyclic, carboxyl, substituted carboxyl or cyano group; ee represents an integer of 0 to 2; Ar_6 and Ar_7 each independently represent an arylene group, a divalent heterocyclic group or a divalent group having a metal complex structure; sa and sb each independently represent 0 or 1; and X_4 represents O, S, SO, SO_2 , Se or Te. When more than one group or atom R_{32} exist, they may be the same or different.

15 Specific examples of the repeating units represented by the formula (11) are as follows.

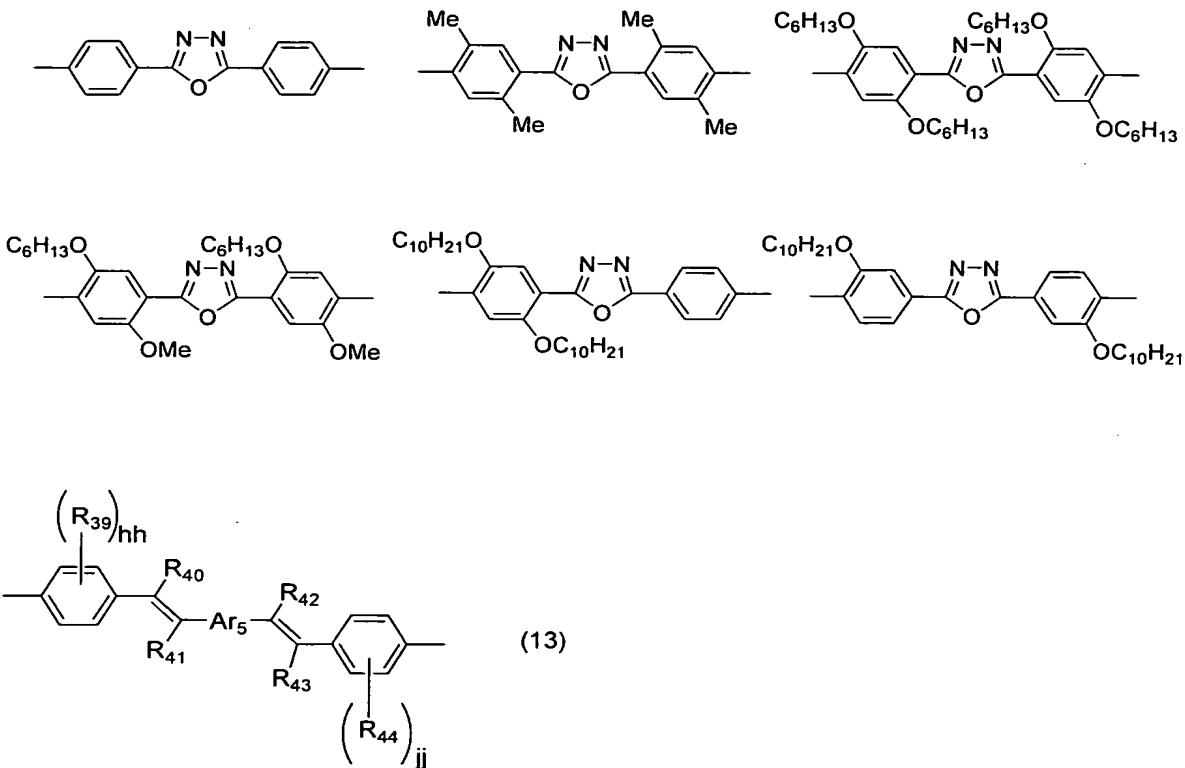


In the above formula, R_{33} and R_{34} each independently represent the same group as the R_{25} in the formula (8); ff and gg each independently represent an integer of 0 to 4; X_5 represents O, S, SO, SO₂, Se, Te, N- R_{35} or 5 SiR₃₆R₃₇; X_6 and X_7 each independently represent N or C- R_{38} ; and R_{35} , R_{36} , R_{37} and R_{38} each independently represent a hydrogen atom, or an alkyl, aryl, arylalkyl or monovalent heterocyclic group. When more than one atom or group R_{33} and more than one atom or group R_{34} exist, 10 they may be the same or different.

Examples of the central five-membered rings in the repeating units represented by the formula (12)

include thiadiazole, oxadiazole, triazole, thiophene, furan and silole.

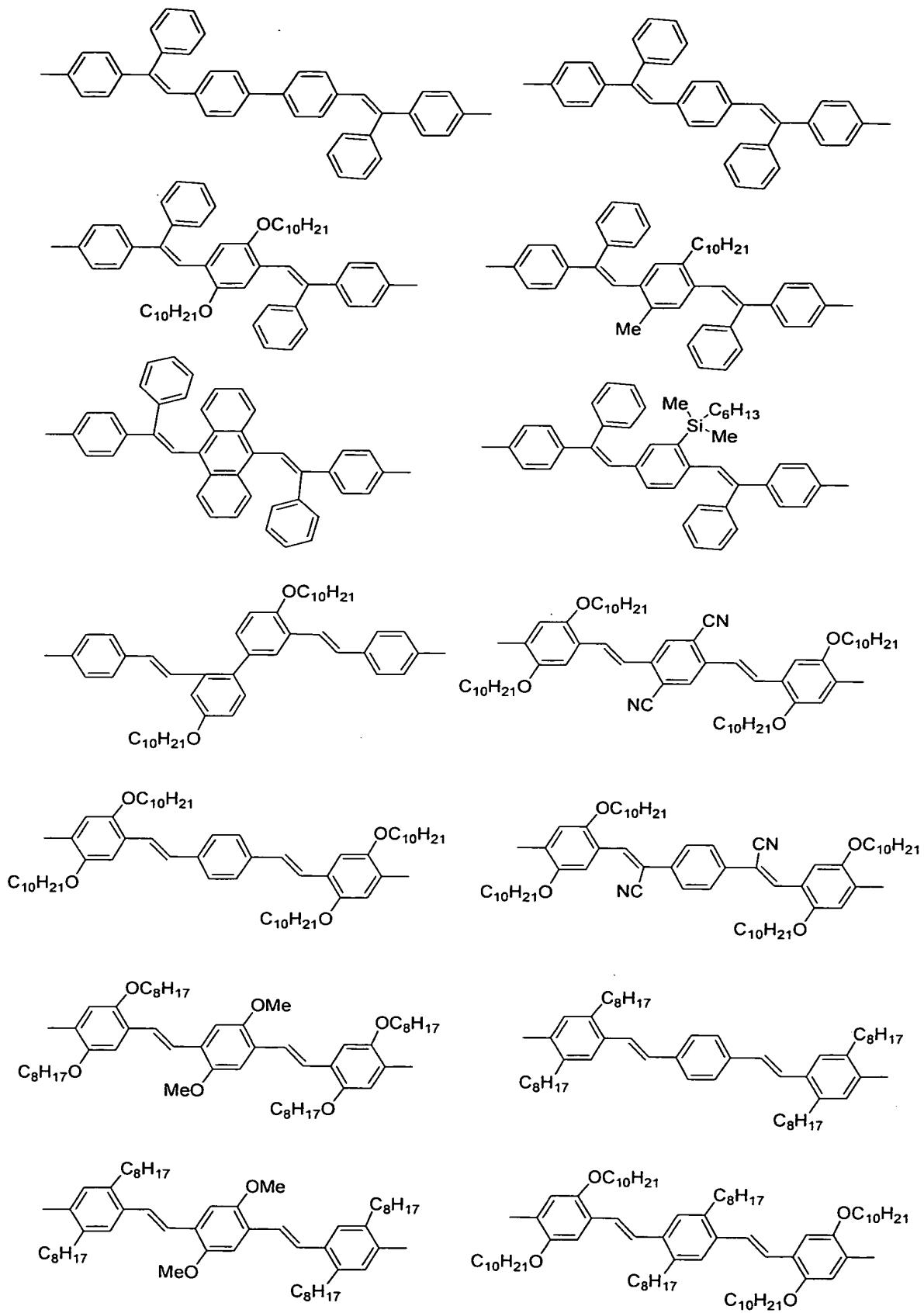
Specific examples of the repeating units represented by the formula (12) are as follows.



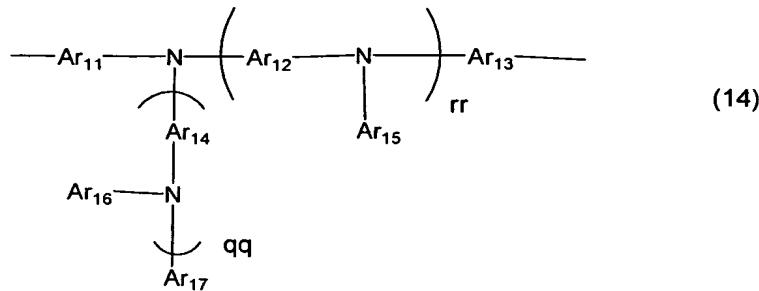
- 5 In the above formula, R₃₉ and R₄₄ each independently represent the same group as the R₂₅ in the formula (8); hh and jj each independently represent an integer of 0 to 4; R₄₀, R₄₁, R₄₂ and R₄₃ each independently represent the same group as the R₂₉ in the formula (10); and Ar₅
- 10 represents an arylene group, a divalent heterocyclic group or a divalent group having a metal complex structure. When more than one atom or group R₃₉ and more than one atom or group R₄₄ exist, they may be the

same or different.

Specific examples of the repeating units represented by the formula (12) are as follows.

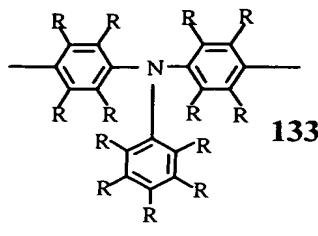


Of the repeating units represented by the above described formula (5), those represented by the following formula (14) are preferable.

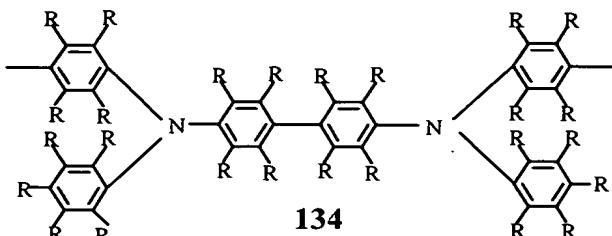


In the above formula, Ar₁₁, Ar₁₂, Ar₁₃ and Ar₁₄ each 5 independently represent an arylene or divalent heterocyclic group; Ar₁₅, Ar₁₆ and Ar₁₇ each independently represent an aryl or monovalent heterocyclic group; and qq and rr each independently represent 0 or 1, wherein 0 ≤ qq + rr ≤ 1.

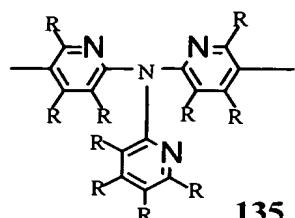
10 Specific examples of the repeating units represented by the above described formula (14) are as follows (formulae 133 to 140).



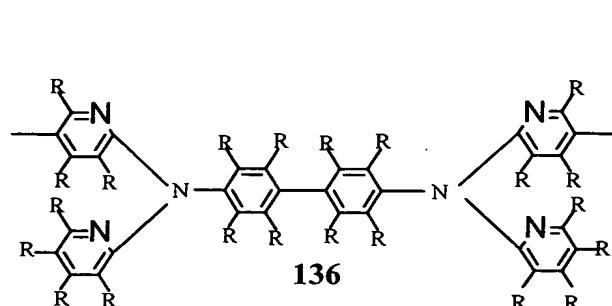
133



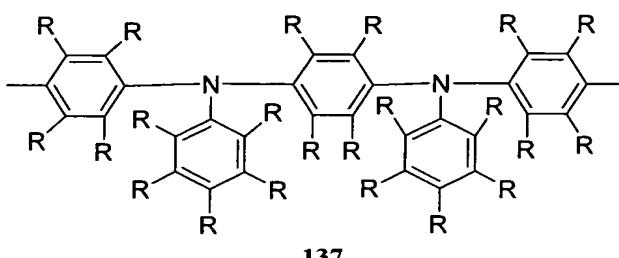
134



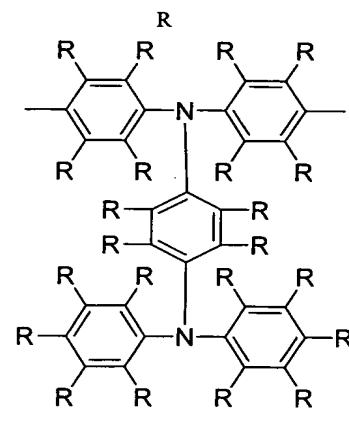
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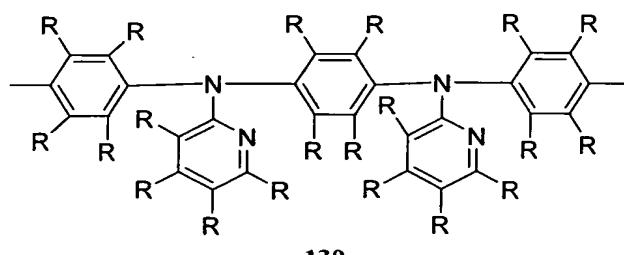
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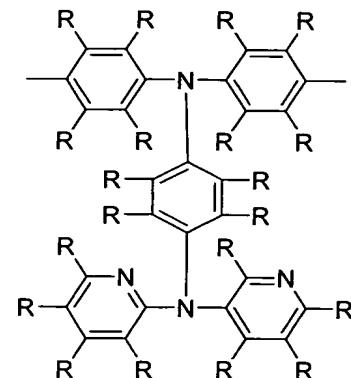
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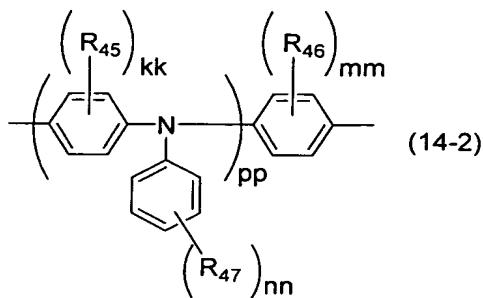
139



140

In the above formulae, R represents the same as that in the above described formulae 1 to 132 and J to 0.

Of the repeating units, other than those represented by the formula (1), which are represented by the formulae (8), (9), (10), (11), (12), (13) and (14), those represented by the formula (14) is more preferable. The repeating units represented by the following formula (14-2) are particularly preferable.



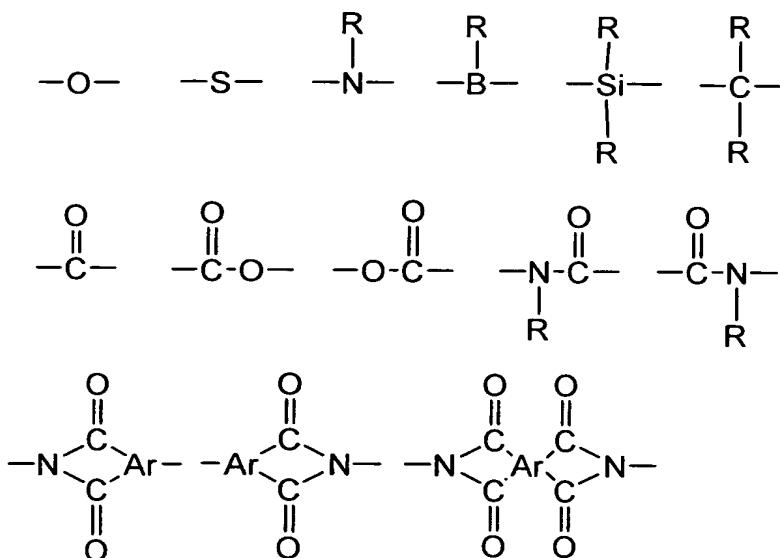
In the above formula, R₄₅, R₄₆ and R₄₇ each independently represent an alkyl, alkoxy, alkylthio, aryl, aryloxy, arylthio, arylalkyl, arylalkoxy, arylalkylthio, arylalkenyl, arylalkynyl, amino, substituted amino, silyl, substituted silyl, silyloxy or substituted silyloxy group, or a halogen atom, or an acyl, acyloxy, imino, amide, imide, monovalent heterocyclic, carboxyl, substituted carboxyl or cyano group; kk and mm each independently represent an integer of 0 to 4; pp represents an integer of 1 to 2; and nn represents an integer of 0 to 5. When more than one atom or group R₄₅, more than one atom or group R₄₆ and more than one atom or group R₄₇ exist, they may be the same or

different.

The polymer may also include repeating units other than those represented by formulae (1) to (14) as long as they do not impair the fluorescence

5 characteristics or charge transport characteristics of the polymer. The repeating units represented by the formulae (1) to (14) or other repeating units may be linked together by non-conjugated units.

Alternatively, the repeating units may include such 10 non-conjugated portions. Examples of the bond-structures include those shown below and combinations of two or more of the same. R in the bond-structures represents a group selected from the group consisting of the same substituents as those described above in 15 connection with R and Ar represents a hydrocarbon group having 6 to 60 carbons.



The polymer of this invention may be a

random, block or graft copolymer. Alternatively, it may be a polymer having a structure somewhere between random, block and graft copolymers; for example, it may be a random copolymer which assumes characteristics of

5 a block copolymer. From the viewpoint of obtaining a light emitting polymer (a light emitting material having a high-molecular-weight) that provides fluorescence or phosphorescence in high quantum yields, a random copolymer assuming characteristics of a block

10 copolymer, or a block or graft copolymer is preferable compared with a perfect random copolymer. Such copolymers include: those having chain branching on their backbones and 3 or more terminals; and dendrimers.

15 The end groups of the polymer of this invention may be protected with a stable protective group, because if polymerization activating groups remain in the polymer, the luminescence characteristics or life of the element formed of the polymer may be

20 reduced. Preferable protective groups are those having a conjugated bond continuous with the conjugated structure of the polymer's backbone, for example, structures combining with an aryl or heterocyclic group via a carbon-carbon bond. Specific examples of such

25 groups include substituents described in Formula 10 in JP-A-9-45478.

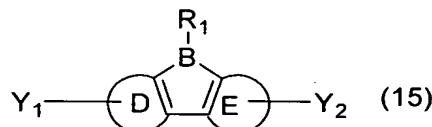
The number average molecular weight, in terms of polystyrene, of the polymer of this invention is 10^3

to 10^8 and preferably 5×10^3 to 10^6 .

Good solvents for the polymer of this invention include, for example, chloroform, methylene chloride, dichloroethane, tetrahydrofuran, toluene, 5 xylene, mesitylene, tetralin, decalin and n-butylbenzene. Normally, 0.1% by weight or more of the polymer of this invention can be dissolved in such solvents, though its depends on the structure or molecular weight of the polymer.

10 Now, methods for producing the polymer of this invention will be described.

The polymer of this invention can be produced by subjecting a compound represented by the following formula (15), as one of its raw materials, to 15 condensation polymerization.



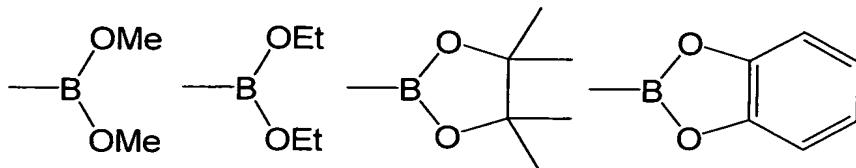
In the above formula, rings D, E and R1 each represent the same as described above. Y1 and Y2 each independently represent substituents that take part in the condensation polymerization.

20 Examples of substituents that take part in the condensation polymerization include halogen atoms, and alkylsulfonate, arylsulfonate, arylalkylsulfonate, borate ester, methyl sulfonium, methyl phosphonium, methyl phosphonate, methyl halide, boric acid, formyl,

cyanomethyl and vinyl groups.

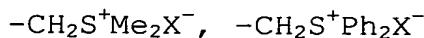
Alkylsulfonate groups include, for example, methanesulfonate, ethanesulfonate and trifluoromethanesulfonate groups. Arylsulfonate groups 5 include, for example, benzenesulfonate and p-toluenesulfonate groups. And arylalkylsulfonate groups include, for example, benzylsulfonate group.

Borate ester groups include, for example, groups represented by the following formulae.



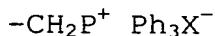
10 In the above formulae, Me represents a methyl group and Et an ethyl group.

Methyl sulfonium groups include, for example, groups represented by the following formulae.



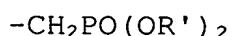
15 In the above formulae, X represents a halogen atom and Ph a phenyl group.

Methyl phosphonium groups include, for example, groups represented by the following formula.



20 In the above formula, X represents a halogen atom.

Methyl phosphonate groups include, for example, groups represented by the following formula.



In the above formula, X represents a halogen atom and R' an alkyl, aryl or arylalkyl group.

Methyl monohalide groups include, for example, methyl fluoride, methyl chloride, methyl

5 bromide and methyl iodide groups.

Preferred substituents that take part in the condensation polymerization reaction vary depending on the type of the polymerization reaction; however, when the reaction is the Yamamoto coupling reaction or the

10 like which uses a zerovalent nickel complex, preferred substituents include, for example, halogen, alkylsulfonate, arylsulfonate and arylalkylsulfonate groups. When the reaction is the Suzuki coupling reaction or the like which uses a nickel or palladium

15 catalyst, preferred substituents include, for example, halogen, borate ester and boric acid groups.

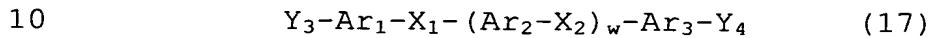
When the polymer of this invention further has repeating units other than those represented by the formula (1), the condensation polymerization can be

20 carried out in the presence of a compound which has two substituents that take part in condensation polymerization and is to be the repeating units other than those represented by the formula (1).

Examples of compounds which have substituents

25 that take part in condensation reaction and are to be repeating units other than those represented by the formula (1) include compounds represented by the formulae (16) to (19) below.

Subjecting not only the compound represented by the above described formula (15) but also a compound represented by any one of the following formulae (16) to (19) to condensation polymerization makes it 5 possible to produce a polymer that has not only the repeating units represented by the formula (1) but also one or more kinds of repeating units represented by the formula (4), (5), (6) or (7).



In the above formulae, Ar_1 , Ar_2 , Ar_3 , X_1 and X_2 each represent the same as above. Y_3 and Y_4 each 15 independently represent a substituent that takes part in the condensation polymerization.

In a method for producing the polymer of this invention, any known condensation reaction can be used as the condensation polymerization reaction, depending 20 on the substituents of the above compounds (15) to (19) that take part in the condensation polymerization reaction.

Methods for producing the polymer of this invention include: for example, polymerization of 25 applicable monomers by the Suzuki coupling reaction or the like which uses a nickel or palladium catalyst; polymerization of applicable monomers by the Grignard reaction; polymerization of applicable monomers by the

Yamamoto coupling reaction or the like which uses a zerovalent nickel complex; polymerization of applicable monomers using an oxidant such as FeCl_3 ; electrochemical oxidative polymerization of applicable monomers; and

5 decomposition of an intermediate polymer having an appropriate leaving group.

Methods in which condensation polymerization produces double bonds in the polymer of this invention include, for example, those described in JP-A-5-202355.

10 Specifically, they include: polymerization of a compound having a formyl group and a compound having a methyl phosphonium group by the Wittig reaction; polymerization of a compound having both formyl group and methyl phosphonium group by the Wittig reaction;

15 polymerization of a compound having a vinyl group and a compound having a halogen atom by the Heck reaction; polycondensation of a compound having two or more methyl monohalide groups by dehydrohalogenation; polycondensation of a compound having two or more

20 methyl sulfonium groups by sulfonium salt decomposition; polymerization of a compound having a formyl group and a compound having a cyanomethyl group by the Knoevenagel reaction; and polymerization of a compound having two or more formyl groups by the

25 McMurry reaction.

Methods in which condensation polymerization produces triple bonds in the backbone of the polymer of this invention include, for example, those using the

Heck reaction or the Sonogashira reaction.

Methods in which condensation polymerization produces neither double bonds nor triple bonds in the polymer of this invention include: for example, 5 polymerization of applicable monomers by the Suzuki coupling reaction; polymerization of applicable monomers by the Grignard reaction; polymerization of applicable monomers using a Ni(0) complex; polymerization of applicable monomers using an oxidant 10 such as FeCl₃; electrochemical oxidative polymerization of applicable monomers; and decomposition of an intermediate polymer having an appropriate leaving group.

Of these methods, polymerization by the 15 Suzuki coupling reaction which uses a nickel or palladium catalyst, polymerization by the Grignard reaction, polymerization by the Yamamoto coupling reaction which uses a zerovalent nickel complex, polymerization by the Wittig reaction, polymerization 20 by the Heck reaction, polymerization by the Sonogashira reaction and polymerization of the Knoevenagel reaction are preferable because of ease of structural control.

The reaction conditions will be described in further detail.

25 In the Wittig, Horner and Knoevenagel reactions, the reactions are carried out using the equivalent or more of, preferably one to three equivalents of alkali to the functional groups of the

compounds used. Alkalies used include, but not limited to, the following: metal alcholates such as potassium t-butoxide, sodium t-butoxide, sodium ethylate and lithium methylate; hydride reagents such as sodium 5 hydride; and amides such as sodium amide. Solvents used include, for example, N,N-dimethylformamide, tetrahydrofuran, dioxane and toluene. Usually the reactions are allowed to progress at room temperature to about 150°C. The reaction time is, for example, 5 10 minutes to 40 hours; however, it may be any time as long as the reactions fully progress. Preferably it is 10 minutes to 24 hours, because the polymerization products need not be left for a long time after the termination of the reactions. The concentration of the 15 compounds used is properly selected from the range of about 0.01% by weight to the maximum concentration to which the compounds are dissolved. If the concentration is too low, the reaction is made less efficient, whereas it is too high, the reaction is 20 difficult to control. Usually the concentration is in the range of 0.1% by weight to 30% by weight. The details of the Wittig reaction are described in, for example, *Organic Reactions*, Vol. 14, 270-490, John Wiley & Sons, Inc., 1965. The details of the 25 Knoevenagel, Wittig and dehydrohalogenation reactions are described in *Makromol. Chem., Macromol. Symp.*, Vol. 12, 229, 1987.

In the Heck reaction, monomers are allowed to

react in the presence of triethylamine with a palladium catalyst. A solvent with a relatively high boiling point, such as N,N-dimethylformamide or N-methylpyrrolidone, is used. The reaction temperature 5 is about 80 to 160°C and the reaction time is about 1 hour to 100 hours. The details of the Heck reaction are described in, for example, *Polymer*, Vol.39, 5241-5244, 1998.

In the Sonogashira reaction, usually monomers 10 are allowed to react in the presence of a base, such as triethylamine, with a palladium catalyst and cuprous iodide in N,N-dimethylformamide, an amine solvent or ether solvent. Usually the reaction temperature is about -50 to 120°C and the reaction time is about 1 hour 15 to 100 hours, though they depend on the reaction conditions or the reactivity of the polymerizable substituents of the monomers. The details of the Sonogashira reaction are described in, for example, *Tetrahedron Letters*, Vol. 40, 3347-3350, 1999 and 20 *Tetrahedron Letters*, Vol. 16, 4467-4470, 1975.

In the Suzuki reaction, monomers are allowed 25 to react by adding the equivalent or more of, preferably 1 to 10 equivalents of an inorganic base such as potassium carbonate, sodium carbonate or barium hydroxide, an organic base such as triethylamine, or an inorganic salt such as cesium fluoride to the monomers and using palladium(tetrakis(triphenylphosphine)) or palladium acetate as a catalyst. The reaction may be

carried out in a two-phase system by using the inorganic salt in an aqueous solution form. Solvents used include, for example, N,N-dimethylformamide, toluene, dimethoxyethane and tetrahydrofuran. The 5 suitable reaction temperature is about 50 to 160°C, though it depends on the solvent used. The temperature may be raised to near the boiling point of the solvent, followed by reflux. The reaction time is about 1 to 200 hours.

10 The details of the Suzuki reaction are described in, for example, *Chem. Rev.*, Vol. 95, 2457, 1995.

Methods which use a zerovalent nickel complex will be described. The methods are divided into two 15 types: one type is to use a zerovalent nickel complex; and the other is to react a nickel salt in the presence of a reductant to produce zerovalent nickel in the system and to react the same.

Zerovalent nickel complexes used include, for 20 example, bis(1,5-cyclooctadiene)nickel(0), (ethylene)bis(triphenylphosphine)nickel(0) and tetrakis(triphenylphosphine)nickel. Of these zerovalent nickel complexes, bis(1,5-cyclooctadiene)nickel(0) is preferable from the 25 viewpoint of general-purpose properties and low cost.

From the viewpoint of better yield, it is preferable to add a neutral ligand.

The term "a neutral ligand" means a ligand

that has neither anion nor cation. Examples of neutral ligands include: nitrogen-containing ligands such as 2,2'-bipyridyl, 1,10-phenanthroline, methylenebisoxazoline and N,N'-

5 tetramethylethylenediamine; and tertiary phosphine ligands such as triphenylphosphine, tritylphosphine, tributylphosphine and triphenoxyphosphine. From the viewpoint of general-purpose properties and low cost, nitrogen-containing ligands are preferable, and from

10 the viewpoint of high reactivity and high yield, 2,2'-bipyridyl is particularly preferable. From the viewpoint of better yield of polymer, a system is particularly preferable which is obtained by adding 2,2'-bipyridyl, as a neutral ligand, to a system

15 containing bis(1,5-cyclooctadiene)nickel(0). Nickel salts used in the methods in which zerovalent nickel is reacted in a system include, for example, nickel chloride and nickel acetate. Reductants used include, for example, zinc, sodium hydride, hydrazine and the

20 derivatives thereof, and lithium aluminum hydride. If necessary, ammonium iodide, lithium iodide or potassium iodide is used as an additive.

Of the production methods of this invention, a method is preferable in which Y_1 , Y_2 , Y_3 and Y_4 each

25 independently represent a halogen atom, or an alkylsulfonate, arylsulfonate or arylalkylsulfonate group and condensation polymerization is carried out in the presence of a zerovalent nickel complex.

In this case, raw material compounds used include, for example, dihalide compounds, bis(alkylsulfonate) compounds, bis(arylsulfonate) compounds, bis(arylalkylsulfonate) compounds, halogen-alkylsulfonate compounds, halogen-arylsulfonate compounds, halogen-arylalkylsulfonate compounds, alkylsulfonate-arylsulfonate compounds, alkylsulfonate-arylalkylsulfonate compounds and arylsulfonate-arylalkylsulfonate compounds.

Of the production methods of this invention, a method is preferable in which Y_1 , Y_2 , Y_3 and Y_4 each independently represent a halogen atom, or an alkylsulfonate, arylsulfonate, arylalkylsulfonate, boric acid or borate ester group, the ratio of the total mole number (J) of the halogen, alkylsulfonate, arylsulfonate and arylalkylsulfonate groups to that (K) of the boric acid and borate ester groups is substantially 1 (usually K/J is in the range of 0.7 to 1.2), and the condensation polymerization is carried out using a nickel or palladium catalyst.

In this case, specific examples of combinations of the raw material compounds used include those of any one selected from the group consisting of dihalide compounds, bis(alkylsulfonate) compounds, bis(arylsulfonate) compounds and bis(arylalkylsulfonate) compounds and any one selected from the group consisting of diboric acid compounds and diborate ester compounds. Alternatively, any one of

halogeno-boric acid compounds, halogeno-borate ester compounds, alkylsulfonate-boric acid compounds, alkylsulfonate-borate ester compounds, arylsulfonate-boric acid compounds, arylsulfonate-borate ester compounds, arylalkylsulfonate-boric acid compounds or arylalkylsulfonate-borate ester compounds is used alone as starting compound.

Generally, it is preferable to subject the organic solvent used in the production of the polymer of this invention to deoxygenation treatment and allow the reaction to progress in an inert atmosphere to suppress side reactions, though it depends on the compound and reaction used. It is also preferable to subject the solvent used to dehydration treatment.

However, this does not necessarily apply to the reactions in a two-phase system: a solvent-water system, such as the Suzuki coupling reaction.

To allow the polymerization reaction to progress, an alkali or an appropriate catalyst may also be added. Such an alkali or catalyst can be selected depending on the type of the reaction. Preferably, an alkali or catalyst is selected which is fully dissolved in the solvent used in the reaction. Methods for mixing an alkali or catalyst with a reaction solution include: for example, a method in which a solution of the alkali or catalyst is slowly added to the reaction solution with stirring in an inert atmosphere such as argon or nitrogen, and a method in which the reaction

solution is slowly added to the solution of the alkali or catalyst.

The polymerization time is usually about 0.5 to 100 hours, though it depends on the type of 5 polymerization. Preferably it is within 10 hours in view of production cost.

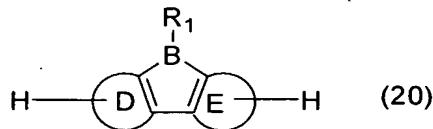
The polymerization temperature is usually about 0 to 200°C, though it depends on the type of polymerization. From the viewpoint of high yield and 10 low heating cost, preferably it is in the range of 20 to 100°C.

When using the polymer of this invention in a polymeric LED, it is preferable to purify monomers to be used by means such as distillation, sublimation, 15 recrystallization or column chromatography before polymerization, because the purity of the polymer affects the LED's performance such as luminescent characteristics. After polymerization, preferably the polymer undergoes purifying treatment by various 20 operations including: separation in common use such as washing with an acid, washing with an alkali, neutralization, washing with water, washing with an organic solvent, reprecipitation, centrifugation, extraction, column chromatography or dialysis; 25 purification; and drying.

Now, methods will be described for producing the compounds represented by the above described formula (15) which are used as the raw materials for

the polymer of this invention.

Methods for producing the compounds represented by the above described formula (15) vary depending on the type of the substituents that take 5 part in the condensation polymerization of the compounds. In a first type of methods, for example, the compounds can be produced by the reaction leading to the introduction of the substituents (Y1 and Y2) that take part in the condensation polymerization 10 reaction into compounds represented by the following formula (20).



In the above formula, R_1 and rings D and E each represent the same as those in the above described formula (1).

15 Specific examples of the first type of methods include: a method in which the compounds represented by the above described formula (15) whose substituents that take part in the condensation polymerization reaction are formyl groups are 20 synthesized by reacting the compounds represented by the above described formula (20) with a formylation reagent; a method in which the compounds represented by the above described formula (15) whose substituents that take part in the condensation polymerization

reaction are monohalogenomethyl groups are synthesized by reducing the above formylated compounds and reacted the reduced compounds with a halogenation reagent; and a method in which the compounds represented by the above 5 described formula (15) whose substituents that take part in the condensation polymerization reaction are vinyl groups are synthesized by reacting the formyl groups of the above formylated compounds with the Wittig reagent or the Horner reagent.

10 The above first type of methods also include a method in which the compounds represented by the above described formula (15) whose substituents that take part in the condensation polymerization reaction are monohalogenomethyl groups are synthesized by 15 reacting the compounds represented by the above described formula (20) with paraform and hydrogen halide.

Further, the above first type of methods also include a method in which the compounds represented by 20 the above described formula (15) whose substituents that take part in the condensation polymerization reaction are halogen atoms are synthesized by reacting the compounds represented by the above described formula (20) with a halogenation reagent or by reacting 25 the compounds represented by the above described formula (20) with a base, followed by reaction with a halogenation reagent.

Further, a method is also included in which

the compounds represented by the above described formula (15) whose substituents that take part in the condensation polymerization reaction are boric acid groups or borate ester groups are synthesized by

5 reacting the compounds represented by the above described formula (15) whose substituents that take part in the condensation polymerization reaction are halogen atoms with a base, followed by the reaction with a boric acid compound. Still further, a method is

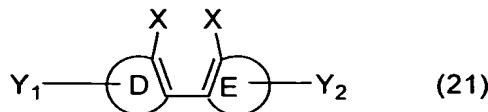
10 also included in which the compounds represented by the above described formula (15) whose substituents that take part in the condensation polymerization reaction are alkylsulfonate, arylsulfonate or arylalkylsulfonate groups are synthesized by decomposing with hydrogen

15 peroxide or the like the boric acid groups of the compounds represented by the above described formula (15) whose substituents that take part in the condensation polymerization reaction are boric acid groups and subjecting the decomposed compounds to

20 sulfonation.

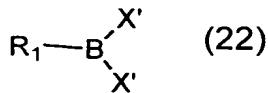
In a second type of methods, the compounds represented by the above described formula (15) can be produced by reacting compounds having substituents that take part in condensation polymerization reaction and

25 represented by the following formula (21) with a boron compound.



In the above formula, Y_1 , Y_2 , and rings D and E each represent the same as those in the above described formula (15). X is a halogen atom. When the rings D and E each have a halogen atom as a substituent or when either Y_1 or Y_2 is a halogen atom, the halogen atom represented by X is more reactive with a base or metal than the halogen atoms included in the rings D and E or represented by Y_1 or Y_2 .

Specific examples of the second type of methods include a method in which the compounds represented by the above described formula (15) are produced by reacting compounds represented by the above described formula (21) with a base, followed by the reaction with a boron compound represented by the following formula (22).



In the above formula, R_1 represents the same as that in the above described formula (1). X' represents a halogen atom or an alkoxy group.

Examples of halogenation reagents used in the production of the compounds represented by the above described formula (15) include: N-halogeno compounds

such as N-chlorosuccinimide, N-chlorophthalimide, N-chlorodiethylamine, N-chlorodibutylamine, N-chlorocyclohexylamine, N-bromosuccinimide, N-bromophthalimide, N-bromoditrifluoromethylamine, N-
5 iodosuccinimide and N-iodophthalimide; fluorine; fluoroxytrifluoromethane; oxygen difluoride; perchloryl fluoride; cobalt fluoride (III); silver fluoride (II); selenium fluoride (IV); manganese fluoride (III); chlorine; iodotrichloride; aluminum
10 trichloride; tellurium chloride (IV); molybdenum chloride; antimony chloride; iron chloride (III); titanium tetrachloride; phosphorus pentachloride; thionyl chloride; bromine; 1,2-dibromoethane; boron tribromide, copper bromide; silver bromide; t-butyl
15 bromide, bromine oxide; iodine; and iodomonochloride.

Examples of bases used in the production of the compounds include: lithium hydride, sodium hydride, potassium hydride, methyl lithium, n-butyllithium, t-butyllithium, phenyllithium, lithium diisopropylamide,
20 lithium hexamethyldisilazide, sodium hexamethyldisilazide and potassium hexamethyldisilazide.

Examples of solvents used in the reaction include: saturated hydrocarbons such as pentane, hexane, heptane, octane and cyclohexane; unsaturated hydrocarbons such as benzene, toluene, ethylbenzene and xylene; saturated halogenated hydrocarbons such as carbon tetrachloride, chloroform, dichloromethane,

chlorobutane, bromobutane, chloropentane, bromopentane, chlorohexane, bromohexane, chlorocyclohexane and bromocyclohexane; unsaturated halogenated hydrocarbons such as chlorobenzene, dichlorobenzene and

5 trichlorobenzene; alcohols such as methanol, ethanol, propanol, isopropanol, butanol and t-butylalcohol; carboxylic acids such as formic acid, acetic acid and propionic acid; ethers such as dimethyl ether, diethyl ether, methyl-t-butylether, tetrahydrofuran,

10 tetrahydropyran and dioxane; amines such as trimethylamine, triethylamine, N,N,N',N'-tetramethylethylenediamine and pyridine; and amides such as N,N-dimethylformamide, N,N-dimethylacetamide, N,N-diethylacetamide and N-methylmorpholine oxide.

15 Any single solvent or mixed solvent of two or more selected from among these solvents can be used depending on the reaction.

The compounds represented by the above formula (15) can be obtained by conventional post-
20 treatment, such as quenching with water, extraction with an organic solvent and evaporating of the solvent, after the reaction.

The isolation and purification of the products can be done by means of separation by
25 chromatography or recrystallization.

The applications of the polymer of this invention will be described.

Normally the polymer of this invention

fluorescences or phosphorescences in the solid state, and it can be used as a polymeric luminous body (a high-molecular-weight light-emitting material). A polymer LED using the polymeric luminous body is a 5 high-performance polymeric LED that can be driven at low voltage and at high efficiency. Accordingly, such a polymeric LED can be suitably used for the backlight of liquid crystal displays, curved-surface or flat surface light sources, segment-type display devices, or 10 units such as dot matrix flat panel displays.

The polymer of this invention can also be used as a laser dye, material for organic solar cells, organic semiconductor for organic transistor, material for conductive thin film such as conductive thin film 15 and organic semiconductor thin film.

Further, the polymer of this invention can also be used as a material for light-emitting thin films that emit fluorescence or phosphorescence.

The polymeric LED of this invention will be 20 described.

The polymeric LED of this invention is characterized in that it has an organic layer between electrodes: an anode and a cathode, which contains the polymer of this invention.

25 The organic layer may be a light-emitting layer, a hole transport layer or an electron transport layer; however, it is preferably a light-emitting layer.

The term "a light-emitting layer" means a layer having the function of emitting light, the term "a hole transport layer" means a layer having the function of transporting holes, and the term "an 5 electron transport layer" means a layer having the function of transporting electrons. The electron transport layer and the hole transport layer are generically called charge transport layer. The polymeric LED may include tow or more of each of the 10 light-emitting layer, hole transport layer and electron transport layer.

When the organic layer is a light-emitting layer, the light-emitting layer as an organic layer may further include a hole transport material, an electron 15 transport material or a light-emitting material. The term "a light-emitting material" means a material that fluorescences and/or phosphorescences.

When mixing the polymer of this invention and a hole transport material, the hole transport material 20 mixed constitutes 1% by weight to 80% by weight and preferably 5% by weight to 60% by weight of the entire mixture. When mixing the polymer of this invention and an electron transport material, the electron transport material mixed constitutes 1% by weight to 80% by 25 weight and preferably 5% by weight to 60% by weight of the entire mixture. And when mixing the polymer of this invention and a light-emitting material, the light-emitting material mixed constitutes 1% by weight

to 80% by weight and preferably 5% by weight to 60% by weight of the entire mixture. When mixing the polymer of this invention, a light-emitting material, and a hole transport material and/or an electron transport material, the fluorescent material mixed constitutes 1% by weight to 50% by weight and preferably 5% by weight to 40% by weight of the entire mixture, the sum of the hole transport material and the electron transport material mixed constitutes 1% by weight to 50% by weight and preferably 5% by weight to 40% by weight of the entire mixture, and the content of the polymer of this invention is 99% by weight to 20% by weight.

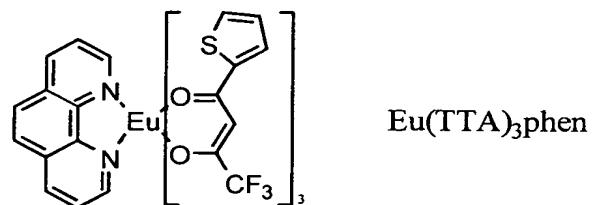
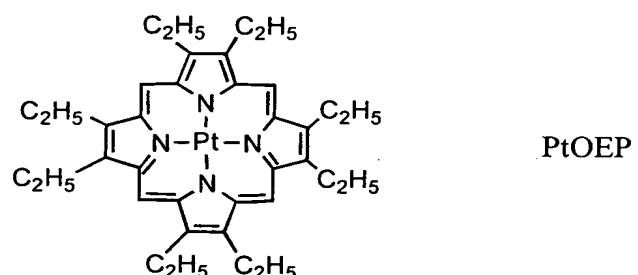
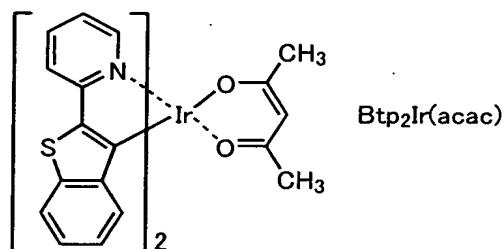
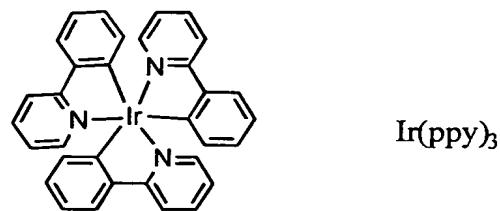
For the hole transport material, the electron transport material and the light-emitting material, a well-known low-molecular-weight compound or polymeric compound can be used; however, preferably a polymeric compound is used. Examples of the polymeric hole transporting, electron transporting and light-emitting materials include: polyfluorene and the derivatives and copolymers thereof; polyarylene and the derivatives and copolymers thereof; polyarylenevinylene and the derivatives and copolymers thereof; and (co)polymers of aromatic amines and their derivatives which are disclosed in, for example, WO 99/13692, WO 99/48160, GB2340304A, WO 00/53656, WO 01/19834, WO 00/55927, GB2348316, WO 00/46321, WO 00/06665, WO 99/54943, WO 99/54385, US5777070, WO 98/06773, WO 97/05184, WO 00/35987, WO 00/53655, WO 01/34722, WO 99/24526, WO

00/22027, WO 00/22026, WO 98/27136, US573636, WO
98/21262, US5741921, WO 97/09394, WO 96/29356, WO
96/10617, EP0707020, WO 95/07955, JP-A-2001-181618, JP-
A-2001-123156, JP-A-2001-3045, JP-A-2000-351967, JP-A-
5 2000-303066, JP-A-2000-299189, JP-A-2000-252065, JP-A-
2000-136379, JP-A-2000-104057, JP-A-2000-80167, JP-A-
10-324870, JP-A-10-114891, JP-A-9-111233 and JP-A-9-
45478.

Examples of applicable low-molecular-weight
10 light-emitting materials include: naphthalene
derivatives; anthracene or the derivatives thereof;
perylene or the derivatives thereof; dyes such as
polymethine, xanthene, coumarin and cyanine; metal
complexes of 8-hydroxyquinoline or the derivatives
15 thereof; aromatic amines; tetraphenylcyclopentadiene or
the derivatives thereof; or tetraphenylbutadiene or the
derivatives thereof.

Specifically, well-known low-molecular-weight
light-emitting materials such as those described in JP-
20 A-57-51781 and JP-A-59-194393 can be used.

Examples of triplet luminous complexes
include: $\text{Ir}(\text{ppy})_3$ and $\text{Btp}_2\text{Ir}(\text{acac})$ with iridium as the
central metal atom; PtOEP with platinum as the central
metal atom; and $\text{Eu}(\text{TTA})_3\text{phen}$ with europium as the
25 central metal atom.



Specific examples of triplet luminous complexes include those described in *Nature* (1998), 395, 151, *Appl. Phys. Lett.* (1999), 75(1), 4, *Proc. SPIE-Int. Soc. Opt. Eng.* (2001), 4105 (Organic Light-

Emitting Materials and Devices IV), 119, *J. Am. Chem. Soc.* (2001), 123, 4304, *Appl. Phys. Lett.* (1997), 71(18), 2596, *Syn. Met.* (1998), 94(1), 103, *Syn. Met.* (1999), 99(2), 1361, *Adv. Mater.*, (1999), 11(10), 852, 5 and *Jpn. J. Appl. Phys.* 34, 1883 (1995).

The composition of this invention contains: at least one kind of material selected from the group consisting of hole transport, electron transport and light-emitting materials; and the polymer of this 10 invention. The composition can be used as a light-emitting material or an electron transport material.

The content ratio of at least one kind of material selected from the group consisting of hole transport, electron transport and light-emitting 15 materials to the polymer of this invention can be determined depending on the application of the composition. However, when the composition is used as a light-emitting material, preferably the content ratio is the same as that of the above described light-emitting 20 layer.

For the film thickness of the light-emitting layer the polymeric LED of this invention has, its optimum value varies depending on the material used, and therefore it can be selected so that the values of 25 the driving voltage and luminous efficiency of the polymeric LED become proper ones. For example, the thickness is 1 nm to 1 μm , preferably 2 nm to 500 nm, and more preferably 5 nm to 200 nm.

Methods for forming the light-emitting layer include, for example, formation of the layer from a solution. Examples of such methods include coating methods such as spin coating, casting, micro gravure 5 coating, gravure coating, bar coating, roll coating, wire bar coating, dip coating, spray coating, screen printing, flexographic printing, offset printing and ink-jet printing. Printing methods such as screen printing, flexographic printing, offset printing and 10 ink-jet printing are preferable because they make pattern forming or multicolor coating easier.

The ink compositions used in printing methods may be any compositions as long as they contain at least one kind of polymer of this invention. They may 15 also contain a hole transport material, an electron transport material, a light-emitting material, a solvent, or additives such as a stabilizer.

The polymer of this invention contained in the above ink composition constitutes 20% by weight to 20 100% by weight and preferably 40% by weight to 100% by weight of the entire ink composition excepting its solvent.

When the ink composition contains a solvent, the solvent constitutes 1% by weight to 99.9% by 25 weight, preferably 60% by weight to 99.5% by weight and more preferably 80% by weight to 99.0% by weight of the entire composition.

Preferred viscosity of the ink composition

varies depending on the printing method employed; however, when the method employed is ink-jet printing or the like in which the ink composition passes through an ink ejecting device, preferably the viscosity is in 5 the range of 1 to 20 mPa·s at 25°C to prevent the ink from clogging or losing straightness of droplet jetting on its ejection.

The solvents used in the ink composition may be any solvents; however, preferably they can uniformly 10 dissolve or disperse the materials, other than the solvent, that constitute the ink composition. When the materials constituting the ink composition are soluble in non-polar solvents, such solvents include: for example, chlorine solvents such as chloroform, 15 methylene chloride and dichloroethane; ether solvents such as tetrahydrofuran; aromatic hydrocarbon solvents such as toluene and xylene; ketone solvents such as acetone and methyl ethyl ketone; and ester solvents such as ethyl acetate, butyl acetate and ethyl 20 cellosolve acetate.

The polymeric LEDs of this invention include: for example, a polymeric LED including an electron transport layer between the cathode and the light-emitting layer; a polymeric LED including a hole 25 transport layer between the anode and the light-emitting layer; and a polymeric LED including an electron transport layer between the cathode and the light emitting layer and a hole transport layer between

the anode and the light-emitting layer.

Specific examples of the polymeric LED structures include the following a) to d).

- a) anode/light-emitting layer/cathode
- 5 b) anode/hole transport layer/light-emitting layer/cathode
- c) anode/light-emitting layer/electron transport layer/cathode
- 10 d) anode/hole transport layer/light-emitting layer/electron transport layer/cathode

(The slash "/" indicates the layers are laminated adjacent to each other. This applies to any "/" below.)

When the polymeric LED of this invention has

15 a hole transport layer, the hole transport material applicable is, for example, polyvinylcarbazole or a derivative thereof; polysilane or a derivative thereof; a polysiloxane derivative having aromatic amine on its side chain or backbone; a pyrazoline derivative; an

20 arylamine derivative; a stilbene derivative; a triphenyldiamine derivative; polyaniline or a derivative thereof; polythiophene or a derivative thereof; polypyrrole or a derivative thereof; poly(p-phenylenevinylene) or a derivative thereof; or

25 poly(2,5-thienylenevinylene) or a derivative thereof.

Specific examples of the hole transport materials include those described in JP-A-63-70257, JP-A-63-175860, JP-A-2-135359, JP-A-2-135361, JP-A-2-

209988, JP-A-3-37992 and JP-A-3-152184.

Of these hole transport materials used for the hole transport layer, preferable is a polymeric hole transport material such as polyvinylcarbazole or a derivative thereof; polysilane or a derivative thereof; a polysiloxane derivative having aromatic amine on its side chain or backbone; polyaniline or a derivative thereof; polythiophene or a derivative thereof; poly(p-phenylenevinylene) or a derivative thereof; or poly(2,5-thienylenevinylene) or a derivative thereof.

And more preferable is polyvinylcarbazole or a derivative thereof; polysilane or a derivative thereof; or a polysiloxane derivative having aromatic amine on its side chain or backbone.

Specific examples of hole transport materials of low molecular weight include pyrazoline derivatives, arylamine derivatives, stilbene derivatives, and triphenyldiamine derivatives. When using a low-molecular-weight hole transport material, it is preferable to disperse it in a polymeric binder.

As the polymeric binder to be mixed, one which does not extremely inhibit the electron transportation and does not have strong absorption of visible light is preferably used. Such a polymeric binder is, for example, poly(N-vinylcarbazole), polyaniline or a derivative thereof, polythiophene or a derivative thereof, poly(p-phenylenevinylene) or a derivative thereof, or poly(2,5-thienylenevinylene) or

a derivative thereof, polycarbonate, polyacrylate, polymethylacrylate, polymethylmethacrylate, polystyrene, polyvinyl chloride, or polysiloxane.

Polyvinylcarbazole or a derivative thereof
5 can be derived from a vinyl monomer by cationic
polymerization or radical polymerization.

Examples of polysilane or the derivatives
thereof include the compounds described in *Chem. Rev.*
Vol. 89, 1359, 1989 or GB 2300196. As methods for
10 synthesizing such compounds, those described in the
above documents can be used. Of the methods, Kipping
method is particularly preferably used.

For polysiloxane or the derivatives thereof,
since the siloxane backbone structure hardly show hole
15 transporting properties, those having a structure of
the above described low-molecular-weight hole transport
material on their side chains or backbone are
preferably used. Such polysiloxane or derivatives
thereof include those having aromatic amine, which is a
20 hole transport material, on their side chains or
backbones.

Film forming methods for the hole
transporting layer are not limited to any specific
ones. However, when using a low-molecular-weight hole
25 transport material, methods are used in which the film
is formed from a mixed solution of the material and a
polymeric binder. When using a polymeric hole
transport material, methods are used in which the film

is formed from a solution of the material.

Solvents used in the methods for forming the layer from a solution may be any solvents as long as they can dissolve hole transport materials. Examples 5 of such solvents include chlorine solvents such as chloroform, methylene chloride and dichloroethane; ether solvents such as tetrahydrofuran; aromatic hydrocarbon solvents such as toluene and xylene; ketone solvents such as acetone and methyl ethyl ketone; and 10 ester solvents such as ethyl acetate, butyl acetate and ethyl cellosolve acetate.

Examples of applicable methods for forming the layer from a solution include spin coating, casting, micro gravure coating, gravure coating, bar 15 coating, roll coating, wire bar coating, dip coating, spray coating, screen printing, flexographic printing, offset printing and ink-jet printing.

The optimum value of the thickness of the hole transport layer varies depending on the material 20 used, and therefore it can be selected so that the values of the driving voltage and luminous efficiency of the polymeric LED are reasonable. However, the layer needs to be so thick at least not to form pinholes therein; but on the other hand, too thick 25 layer is not preferable because the driving voltage of the element increases. Accordingly, the thickness of the hole transport layer is, for example, 1 nm to 1 μm , preferably 2 nm to 500 nm, and more preferably 5 nm to

200 nm.

When the polymeric LED of this invention has an electron transport layer, well known compounds can be used as the electron transport materials. Such a 5 compound is, for example, a metal complex of: an oxadiazole derivative; anthraquinodimethane or a derivative thereof; benzoquinone or a derivative thereof; naphthoquinone or a derivative thereof; anthraquinone or a derivative thereof; 10 tetracyanoanthraquinodimethane or a derivative thereof; a fluorenone derivative; diphenyldicyanoethylene or a derivative thereof; or a diphenoxyl derivative; 8-hydroxyquinoline or a derivative thereof, polyquinoline or a derivative thereof, polyquinoxaline or a 15 derivative thereof, or polyfluorene or a derivative thereof.

Specific examples of the electron transport materials include those described in JP-A-63-70257, JP-A-63-175860, JP-A-2-135359, JP-A-2-135361, JP-A-2-209988, JP-A-3-37992 and JP-A-3-152184.

Of these electron transport materials used for the electron transport layer, preferable are metal complexes of: oxadiazole derivatives; benzoquinone or the derivatives thereof; anthraquinone or the 25 derivatives thereof; 8-hydroxyquinoline or the derivative thereof, polyquinoline or the derivatives thereof, polyquinoxaline or the derivatives thereof, or polyfluorene or the derivatives thereof. More

preferable are 2-(4-biphenylyl)-5-(4-t-butylphenyl)-1,3,4-oxadiazole, benzoquinone, anthraquinone, tris(8-quinolinol)aluminum, and polyquinoline.

Film forming methods for the electron transporting layer are not limited to any specific ones. However, when using a low-molecular-weight electron transport material, methods are used in which the film is formed from a powder of the material by vacuum deposition or from a solution of the material or the material in the molten state. When using a polymeric electron transport material, methods are used in which the film is formed from a solution of the material or the material in the molten state. When forming the film from a solution of a material or a material in the molten state, any one of the above described polymeric binders may be used together.

Solvents used in the methods for forming the layer from a solution may be any solvents as long as they can dissolve electron transport materials and/or polymeric binders. Examples of such solvents include chlorine solvents such as chloroform, methylene chloride and dichloroethane; ether solvents such as tetrahydrofuran; aromatic hydrocarbon solvents such as toluene and xylene; ketone solvents such as acetone and methyl ethyl ketone; and ester solvents such as ethyl acetate, butyl acetate and ethyl cellosolve acetate.

Examples of applicable methods for forming the layer from a solution of the material or the

material in the molten state include spin coating, casting, micro gravure coating, gravure coating, bar coating, roll coating, wire bar coating, dip coating, spray coating, screen printing, flexographic printing, 5 offset printing and ink-jet printing.

The optimum value of the thickness of the electron transport layer varies depending on the material used, and therefore it can be selected so that the values of the driving voltage and luminous 10 efficiency of the polymeric LED are reasonable. However, the layer needs to be so thick at least not to form pinholes therein; but on the other hand, too thick layer is not preferable because the driving voltage of the element increases. Accordingly, the thickness of 15 the electron transport layer is, for example, 1 nm to 1 μ m, preferably 2 nm to 500 nm, and more preferably 5 nm to 200 nm.

Of the charge transport layers provided adjacent to electrodes, those having the function of 20 improving the efficiency of charge injection from the electrodes and of reducing the driving voltage of the element are sometimes referred to as charge injection layer (hole injection layer, electron injection layer).

To improve the adhesion to electrodes or 25 improve the charge injection from the electrodes, the above described charge injection layer or an insulating layer 2 nm or less thick may be provided adjacent to each electrode. Further, to improve the adhesion

between interfaces or prevent the mixture of the same, a thin buffer layer may be inserted in each interface of the electron transport layer and the light-emitting layer.

5 The order, number and thickness of the layers laminated may be selected taking into consideration the luminous efficiency or life time of the element.

Examples of the polymeric LEDs of this invention provided with a charge injection layer(s) (an 10 electron injection layer (s), a hole injection layer (s)) include: those provided with a charge injection layer adjacent to the cathode and those provided with a charge injection layer adjacent to the anode.

Specific examples include the following 15 structures e) to p).

- e) anode/charge injection layer/light-emitting layer/cathode
- f) anode/ light-emitting layer/ charge injection layer /cathode
- 20 g) anode/charge injection layer/light-emitting layer/charge injection layer/cathode
- h) anode/charge injection layer/hole transport layer/light-emitting layer/cathode
- i) anode/hole transport layer/light-emitting 25 layer/charge injection layer/ cathode
- j) anode/charge injection layer/hole transport layer/light-emitting layer/charge injection layer/cathode

- k) anode/charge injection layer/light-emitting layer/electron transport layer/cathode
- l) anode/light-emitting layer/electron transport layer/charge injection layer /cathode
- 5 m) anode/charge injection layer/light-emitting layer/electron transport layer/charge injection layer/cathode
- n) anode/charge injection layer/hole transport layer/light-emitting layer/electron transport
- 10 layer/cathode
- o) anode/hole transport layer/light-emitting layer/electron transport layer/charge injection layer/cathode
- p) anode/charge injection layer/hole transport
- 15 layer/light-emitting layer/electron transport layer/charge injection layer/cathode

Specific examples of the charge injection layers include: a layer that contains a conductive polymer; a layer that is provided between the anode and 20 a hole transport layer and contains a material having an ionization potential between that of the anode material and that of the hole transport material contained in the hole transport layer; and a layer that is provided between the cathode and an electron transport layer and contains a material having an 25 electron affinity between that of the cathode material and that of the electron transport material contained in the electron transport layer.

When the above described charge injection layer is a layer that contains a conductive polymer, the electric conductivity of the conductive polymer is preferably 10^{-5} S/cm or more and 10^3 S/cm or less. To 5 decrease the leak current among light-emitting pixels, the electric conductivity is preferably 10^{-5} S/cm or more and 10^2 S/cm or less and more preferably 10^{-5} S/cm or more and 10^1 S/cm or less.

Usually, an appropriate amount of ion is 10 doped into the conductive polymer to keep the electric conductivity of the same 10^{-5} S/cm or more and 10^3 S/cm or less.

The kind of the ion doped is anion when the charge injection layer is a hole injection layer, while 15 it is cation when the charge injection layer is an electron injection layer. Examples of the anions include polystrenesulfonic acid ion, alkylbenzenesulfonic acid ion and camphosulfonic acid ion. Examples of the cations include lithium ion, 20 sodium ion, potassium ion and tetrabutylammonium ion.

The thickness of the charge injection layer is, for example, 1 nm to 100 nm and preferably 2 nm to 50 nm.

The materials used for the charge injection 25 layers can be properly selected taking into consideration the materials of the electrodes and their adjacent layers. The materials include: for example, conductive polymers such as polyaniline and the

derivatives thereof; polythiophene and the derivatives thereof; polypyrrole and the derivatives thereof; polyphenylenevinylene and the derivatives thereof; polythiylenevinylene and the derivatives thereof;

5 polyquinoline and the derivatives thereof; polyquinoxaline and the derivatives thereof; and polymers having an aromatic amine structure on their backbones or side chains, metal phthalocyanine (copper phthalocyanine), and carbon.

10 The insulating layer 2 nm or less thick has the function of making charge injection easy. Examples of the materials for the insulating layer include metal fluorides, metal oxides and organic insulating materials. Examples of the polymeric LEDs provided

15 with an insulating layer(s) 2 nm or less thick include: those provided with an insulating layer 2 nm or less adjacent to the cathode and those provided with an insulating layer 2 nm or less adjacent to the anode.

Specific examples include the following

20 structures q) to ab).

q) anode/insulating layer 2 nm or less thick/light-emitting layer/cathode

r) anode/light-emitting layer/insulating layer 2 nm or less thick/ cathode

25 s) anode/insulating layer 2 nm or less thick/light-emitting layer/insulating layer 2 nm or less thick/cathode

t) anode/insulating layer 2 nm or less thick/hole

transport layer/light-emitting layer/cathode

- u) anode/hole transport layer/light-emitting layer/insulating layer 2 nm or less thick/ cathode
- v) anode/insulating layer 2 nm or less thick/hole

5 transport layer/light-emitting layer/insulating layer 2 nm or less thick/cathode

- w) anode/insulating layer 2 nm or less thick/light-emitting layer/electron transport layer/ cathode
- x) anode/light-emitting layer/electron transport

10 layer/insulating layer 2 nm or less thick/cathode

- y) anode/insulating layer 2 nm or less thick/light-emitting layer/electron transport layer/insulating layer 2 nm or less thick/cathode
- z) anode/insulating layer 2 nm or less thick/hole

15 transport layer/light-emitting layer/electron transport layer/cathode

- aa) anode/hole transport layer/light-emitting layer/electron transport layer/insulating layer 2 nm or less thick/cathode

20 ab) anode/insulating layer 2 nm or less thick/hole transport layer/light-emitting layer/electron transport layer/insulating layer 2 nm or less thick/cathode

The substrate that constitutes the polymeric LED of this invention may be any substrate as long as

25 it does not undergo changes when electrodes or organic layers are formed on it. Examples of such substrates include glass, plastic, polymeric film and silicon substrates. When the substrate is not transparent,

preferably the electrode opposite to the substrate is transparent or semitransparent.

Usually, at least any one of the anode and cathode the polymeric LED of this invention has is 5 transparent or semitransparent. Preferably, the anode is transparent or semitransparent.

As the material for the anode, a conductive metal oxide film, a semitransparent metal thin film or the like is used. Specifically, a film (e.g., NESA) 10 formed of a conductive glass comprising indium oxide, zinc oxide, tin oxide, and any of their complexes, such as indium tin oxide (ITO) and indium zinc oxide, or gold, platinum, silver or copper is used. ITO, indium zinc oxide and tin oxide are preferable materials. 15 Examples of the methods for forming the anode include vacuum deposition, sputtering, ion plating and plating. An organic transparent conductive film such as polyaniline or a derivative thereof or polythiophene or a derivative thereof may also be used as the anode.

20 The film thickness of the anode can be properly selected taking into consideration the light transmittivity and the electrical conductivity. It is, for example, 10 nm to 10 μm , preferably 20 nm to 1 μm , and more preferably 50 nm to 500 nm.

25 To make charge injection easy, a layer composed of a phthalocyanine derivative, a conductive polymer or carbon, or a layer composed of a metal oxide, a metal fluoride or an organic insulating

material whose average thickness is 2 nm or less may be provided on the anode.

As the materials for the cathode used in the polymeric LED of this invention, low work-function materials are preferable. Examples of such materials include: metals such as lithium, sodium, potassium, rubidium, cesium, beryllium, magnesium, calcium, strontium, barium, aluminum, scandium, vanadium, zinc, yttrium, indium, cerium, samarium, europium, terbium, ytterbium; the alloys of two or more of the above metals or the alloys of one or more of the above metals with at least one selected from gold, silver, platinum, copper, manganese, titanium, cobalt, nickel, tungsten or tin; and graphite or graphite intercalation compounds. Examples of the alloys include magnesium-silver, magnesium-indium, magnesium-aluminum, indium-silver, lithium-aluminum, lithium-magnesium, lithium-indium and calcium-aluminum alloys. The cathode is allowed to have a laminated structure of two or more layers.

The film thickness of the cathode can be properly selected taking into consideration the electrical conductivity and the durability. It is, for example, 10 nm to 10 μm , preferably 20 nm to 1 μm , and more preferably 50 nm to 500 nm.

Examples of the methods for forming the cathode include vacuum deposition, sputtering, and laminating in which a metal thin film is hot pressing.

A layer composed of a conductive polymer or a layer composed of a metal oxide, a metal fluoride or an organic insulating material whose average thickness is 2 nm or less may be provided between the cathode and 5 the organic layer. After the formation of the cathode, a protective layer for protecting the polymeric LED may also be mounted on the cathode. To use the polymeric LED stably and for a long time, it is preferable to mount a protective layer and/or a protective cover on 10 the cathode to protect the element from the outside.

For the protective layer, a polymer, metal oxide, metal fluoride or metal boride can be used. For the protective cover, a glass sheet or a plastic sheet whose surface has undergone low water-permeability 15 treatment can be used. A method is preferably used in which the above described protective cover and the element substrate are tightly adhered with a thermo-set resin or photo-set resin. If a space is kept using a spacer, it is easy to prevent the element from being 20 damaged. If an inert gas such as nitrogen or argon is included in the space, it is possible to prevent the cathode from being oxidized. If a desiccating agent such as barium oxide is placed in the space, it is easy 25 to suppress the element from being damaged by water adsorbed on it during the production process.

Preferably, any one or more of the means are employed.

The polymeric LED can be used as a surface light source, segment display unit, dot matrix display

unit, or the backlight of a liquid crystal display unit.

To obtain surface light emission using the polymeric LED of this invention, a surface anode and a 5 surface cathode should be arranged so that they are superposed. To obtain patterned light emission, a method is employed in which a mask with a patterned window is provided on the surface of the surface light-emitting element, in which the organic layer of the 10 non-light-emitting portion is formed to be extremely thick so that the portion does not substantially emit light, or in which either anode or cathode or both of them are formed to have a pattern. If any one of the above method is employed to form a pattern and some 15 electrodes are arranged so that they can be each independently set at ON/OFF, a segment display unit that can display numerals, letters or simple signs is obtained. To produce a dot matrix display unit, both anodes and cathodes are formed in stripes and arranged 20 so that they lie at right angles to each other. A method in which polymeric luminous body with more than one kind of luminescent color is color-coded or a method in which a color filter or fluorescence conversion filter is used makes possible partial color 25 display or multicolor display. Dot matrix elements can be passive-matrix ones, or if they are combined with TFT, they can be active-matrix elements. These display elements can be used as display units of computer,

televisions, hand-held PCs, mobile phones, car navigation systems, or view finders of video cameras.

Further, since the above described surface light-emitting devices are spontaneous-emission-thin-
5 type elements, they can be suitably used as the surface light source for the backlight of liquid crystal display units or the light source for surface lighting. If a flexible substrate is used, they can be used as curved light sources or curved display units.

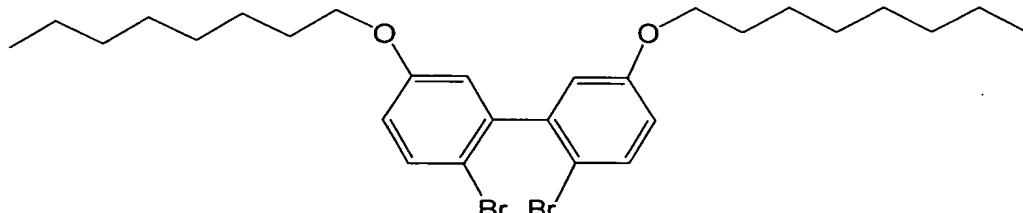
10 In the following, this invention will be described in detail by means of examples. However, the examples are not intended to limit the scope of this invention.

The number average molecular weight herein
15 shown was obtained in terms of polystyrene by gel permeation chromatography (GPC) using chloroform as a solvent.

Synthetic Example 1

<Synthesis of 2,2'-dibromo-5,5'-dioctyloxy-1,1'-
20 biphenyl>

25



3,3'-dioctyloxy-1,1'-biphenyl as a raw material was synthesized by the octylation of 3-

bromophenol in ethanol, followed by the Yamamoto coupling reaction.

133 g of 3,3'-dioctyloxy-1,1'-biphenyl synthesized as above was dissolved in 1820 ml of dried 5 N,N-dimethylformamide. A solution of 117.5 g of N-bromosuccinimide in 910 ml of N,N-dimethylformamide was added dropwise at 0°C (in a dry ice-methanol bath) over 60 minutes. After completion of the addition, the mixture was brought to room temperature and stirred 10 over night.

The reaction solution was poured into water, extracted with n-hexane, followed by evaporating of the solvent to yield 179 g of crude product.

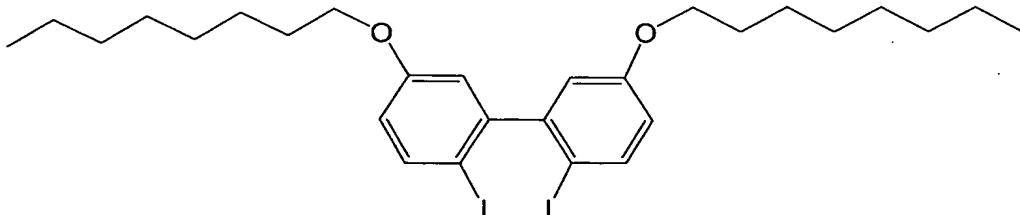
Recrystallization of the crude product was repeated 15 with 2-propanol to yield 122 g of 2,2'-dibromo-5,5'-dioctyloxy-1,1'-biphenyl.

¹H-NMR (300 MHz/CDCl₃):

δ (ppm) = 0.88 [t, 6H], 1.2-1.8 [m, 24H], 3.95 [t, 4H], 6.7-6.8 [m, 4H], 7.52 [d, 2H]

20 Synthetic Example 2

<Synthesis of 2,2'-diiodo-5,5'-dioctyloxy-1,1'-biphenyl>



4.05 g of chipped magnesium was put in a 500 ml three-neck flask in an atmosphere of nitrogen. A solution of 45 g of 2,2'-dibromo-5,5'-dioctyloxy-1,1'-biphenyl synthesized as above in 200 ml of

5 tetrahydrofuran was prepared in another flask, and 20 ml of the solution was added to the flask containing magnesium. Five drops of 1,2-dibromoethane as an initiator was added to the magnesium mixture and heated. Once an exothermic reaction was initiated, the

10 rest of the solution was added dropwise to the mixture over 30 minutes. After completion of the addition of the solution, the reaction was allowed to progress under reflux for 1 hour. Then, the reaction solution was cooled to 0°C, and a solution of 44.2 g of iodine in

15 150 ml of tetrahydrofuran was added dropwise. After completion of the addition, the reaction solution was stirred at room temperature overnight.

The reaction solution was poured into water, extracted with chloroform, followed by washing with an

20 aqueous solution of sodium thiosulfate and a saturated salt solution. Then, the reaction solution was dried with sodium sulfate, followed by evaporating the solvent to yield 53 g of crude product. The crude product was recrystallized with 2-propanol to yield 43

25 g of 2,2'-diiodo-5,5'-dioctyloxy-1,1'-biphenyl.

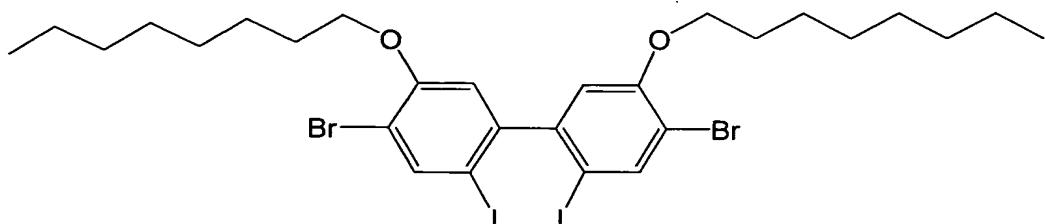
¹H-NMR (200 MHz/CDCl₃):

δ (ppm) = 0.90 [t, 6H], 1.2-1.8 [m, 24H], 3.93 [t, 4H],
6.6-6.8 [m, 4H], 7.74 [d, 2H]

MS (APCI (+)): M⁺ 662

Synthetic Example 3

<Synthesis of 4,4'-dibromo-2,2'-diiodo-5,5'-dioctyloxy-1,1'-biphenyl>



5 37 g of 2,2'-diiodo-5,5'-dioctyloxy-1,1'-biphenyl synthesized as above was put in a 1 L flask in an atmosphere of nitrogen and 800 ml of trimethyl phosphate was added to dissolve the same. Then, 10.6 g of iodine was added and a solution of 19 g of bromine
10 in 70 ml of trimethyl phosphate was added dropwise. After 4-hour stirring, a solution of 9.5 g of bromine in 35 ml of trimethyl phosphate was added dropwise to the mixture. After completion of the addition of the solution, the mixture was stirred overnight. The
15 reaction solution was poured into water, extracted with chloroform, followed by washing with an aqueous solution of sodium thiosulfate and a saturated salt solution. Then, the reaction solution was dried with sodium sulfate, followed by evaporating the solvent to
20 yield 46 g of crude product. The crude product was purified by silica gel chromatography (cyclohexane : toluene = 20 : 1) to yield 20.5 g of 4,4'-dibromo-2,2'-

diiodo-5,5'-dioctyloxy-1,1'-biphenyl.

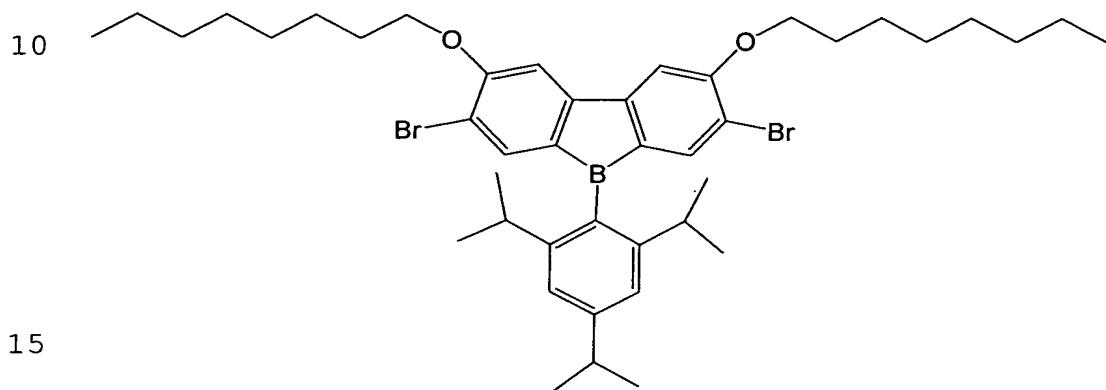
¹H-NMR (200 MHz/CDCl₃):

δ (ppm) = 0.88 [t, 6H], 1.2-1.9 [m, 24H], 3.99 [m, 4H],
6.70 [s, 2H], 8.03 [s, 2H]

5 MS (APCI (+)): M⁺ 820

Synthetic Example 4

<Synthesis of 3,7-dibromo-5-(2,4,6-triisopropylphenyl)-2,8-dioctyloxy-5H-dibenzo(b, d)borole>



2.0 g of 4,4'-dibromo-2,2'-diiodo-5,5'-dioctyloxy-1,1'-biphenyl synthesized as above was put in a 100 ml flask in an atmosphere of nitrogen and 20 ml of tetrahydrofuran was added to dissolve the same. Then, the tetrahydrofuran solution was cooled to -90°C and 3.4 ml of 1.6M hexane solution was added dropwise. After 1-hour stirring, a solution of 1.5 g of magnesium bromide in 20 ml of tetrahydrofuran was added, warmed to room temperature, and stirred for 1 hour. The mixture was cooled again to -90°C, and 1.01 g of (2,4,6-triisopropylphenyl)dimethoxyborane was added. After warming, the mixture was allowed to react under reflux

for 12 hours.

After evaporating the solvent, the resultant product was purified twice by silica gel chromatography (cyclohexane/toluene) to yield 0.47 g of 3,7-dibromo-5-
5 (2,4,6-trimethylphenyl)-2,8-dioctyloxy-5H-dibenzo(b,
d)borole.

¹H-NMR (200 MHz/CDCl₃):

δ (ppm) = 0.89 [t, 6H], 1.1-1.6 [m, 38H], 1.89 [m, 4H],
2.44 [m, 2H], 2.93 [m, 1H], 4.17 [t, 4H], 6.89 [s, 2H],
10 7.01 [s, 2H], 7.50 [s, 2H]

MS (APCI (+)): M⁺ 781

Example 1 (condensation polymerization)

<Synthesis of Polymer 1>

0.41 g of 3,7-dibromo-5-(2,4,6-
15 trimethylphenyl)-2,8-dioctyloxy-5H-dibenzo(b, d)borole,
0.15 g of N,N'-bis(4-bromophenyl)-N,N'-bis(4-n-
butylphenyl)-1,4-phenylenediamine and 0.55 g of 2,2'-
bipyridyl were put in a reactor, and the reaction
system was purged with argon gas. 40 ml of
20 tetrahydrofuran (dehydration solvent) having been
subjected to bubbling by argon gas to be deaerated in
advance was added to the mixture. Then, 1.0 g of
bis(1,5-cyclooctadiene)nickel(0) was added to the mixed
solution, stirred at room temperature for 10 minutes,
25 and allowed to react at 60°C for 3 hours. The reaction
was carried out in an atmosphere of nitrogen.

After the reaction, the reaction solution was
cooled, and poured into a mixed solution of 100 ml of

methanol/200 ml of ion-exchanged water, followed by stirring for about 1 hour. Then, the precipitate was filtered, dried under reduced pressure, and dissolved in 40 ml of toluene. After that, 40 ml of 1N 5 hydrochloric acid was added, and the mixed solution was stirred for 1 hour. After removing the water layer, 40 ml of aqueous ammonia was added to the organic layer and stirred for 1 hour, and the water layer was removed. The resultant solution was purified through 10 an alumina column, the recovered toluene solution was added dropwise to 200 ml of methanol and stirred, and the precipitate was filtered and dried under reduced pressure for 2 hours. The polymer yield was 20 mg. The polymer was referred to as polymer 1.

15 The number average molecular weight and the weight average molecular weight, in terms of polystyrene, of the polymer 1 was 6.1×10^3 and 9.9×10^3 , respectively.

Example 2

20 A thin film of the polymer 1 was formed by spin-coating a 0.2% by weight chloroform solution of the polymer 1 onto quartz. The fluorescent spectrum of the thin film was measured using a fluorescence spectrophotometer (Hitachi Ltd.: 850). The polymer 1 25 has intense fluorescence and the fluorescence peak was at a wavelength of 564 nm.

The polymer of this invention is a novel polymer that can be used as a light-emitting material or a charge transport material and be used in ink compositions or polymeric light-emitting devices.